

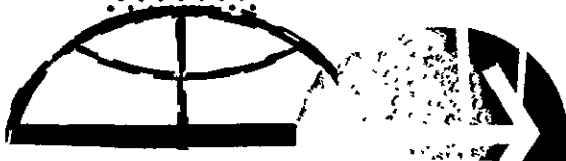


NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MSC INTERNAL NOTE NO. 66-FM-79

August 12, 1966

**A PARAMETRIC STUDY OF CENTRAL
ANGLE OF TRAVEL AND TIME FOR
REENTRY FROM NEAR-EARTH ORBITS**

By William R. Pruett
Flight Analysis Branch



**MISSION PLANNING AND ANALYSIS DIVISION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS**

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FIGURES

Figure		Page
1	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 100$ nautical miles and $h_p = 80$ nautical miles	
	(a) Retrograde $\Delta V = 100$ fps	3
	(b) Retrograde $\Delta V = 300$ fps	4
	(c) Retrograde $\Delta V = 500$ fps	5
	(d) Retrograde $\Delta V = 700$ fps	6
2	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 150$ nautical miles and $h_p = 80$ nautical miles	
	(a) Retrograde $\Delta V = 100$ fps	7
	(b) Retrograde $\Delta V = 300$ fps	8
	(c) Retrograde $\Delta V = 500$ fps	9
	(d) Retrograde $\Delta V = 700$ fps	10
3	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 175$ nautical miles and $h_p = 80$ nautical miles	
	(a) Retrograde $\Delta V = 100$ fps	11
	(b) Retrograde $\Delta V = 300$ fps	12
	(c) Retrograde $\Delta V = 500$ fps	13
	(d) Retrograde $\Delta V = 700$ fps	14
4	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 200$ nautical miles and $h_p = 80$ nautical miles	
	(a) Retrograde $\Delta V = 100$ fps	15
	(b) Retrograde $\Delta V = 300$ fps	16
	(c) Retrograde $\Delta V = 500$ fps	17
	(d) Retrograde $\Delta V = 700$ fps	18

5	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 100$ nautical miles and $h_p = 85$ nautical miles	
(a)	Retrograde $\Delta V = 100$ fps	19
(b)	Retrograde $\Delta V = 300$ fps	20
(c)	Retrograde $\Delta V = 500$ fps	21
(d)	Retrograde $\Delta V = 700$ fps	22
6	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 100$ nautical miles $h_p = 87$ nautical miles	
(a)	Retrograde $\Delta V = 100$ fps	23
(b)	Retrograde $\Delta V = 300$ fps	24
(c)	Retrograde $\Delta V = 500$ fps	25
(d)	Retrograde $\Delta V = 700$ fps	26
7	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 150$ nautical miles and $h_p = 87$ nautical miles	
(a)	Retrograde $\Delta V = 100$ fps	27
(b)	Retrograde $\Delta V = 300$ fps	28
(c)	Retrograde $\Delta V = 500$ fps	29
(d)	Retrograde $\Delta V = 700$ fps	30
8	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 161$ nautical miles and $h_p = 87$ nautical miles	
(a)	Retrograde $\Delta V = 100$ fps	31
(b)	Retrograde $\Delta V = 300$ fps	32
(c)	Retrograde $\Delta V = 500$ fps	33
(d)	Retrograde $\Delta V = 700$ fps	34

9	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 200$ nautical miles and $h_p = 87$ nautical miles	
(a)	Retrograde $\Delta V = 100$ fps	35
(b)	Retrograde $\Delta V = 300$ fps	36
(c)	Retrograde $\Delta V = 500$ fps	37
(d)	Retrograde $\Delta V = 700$ fps	38
10	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 100$ nautical miles and $h_p = 90$ nautical miles	
(a)	Retrograde $\Delta V = 100$ fps	39
(b)	Retrograde $\Delta V = 300$ fps	40
(c)	Retrograde $\Delta V = 500$ fps	41
(d)	Retrograde $\Delta V = 700$ fps	42
11	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 150$ nautical miles and $h_p = 90$ nautical miles	
(a)	Retrograde $\Delta V = 100$ fps	43
(b)	Retrograde $\Delta V = 300$ fps	44
(c)	Retrograde $\Delta V = 500$ fps	45
(d)	Retrograde $\Delta V = 700$ fps	46
12	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 200$ nautical miles $h_p = 90$ nautical miles	
(a)	Retrograde $\Delta V = 100$ fps	47
(b)	Retrograde $\Delta V = 300$ fps	48
(c)	Retrograde $\Delta V = 500$ fps	49
(d)	Retrograde $\Delta V = 700$ fps	50

13	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 120$ nautical miles and $h_p = 100$ nautical miles ^a	
(a)	Retrograde $\Delta V = 100$ fps	51
(b)	Retrograde $\Delta V = 300$ fps	52
(c)	Retrograde $\Delta V = 500$ fps	53
(d)	Retrograde $\Delta V = 700$ fps	54
14	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 150$ nautical miles and $h_p = 100$ nautical miles ^a	
(a)	Retrograde $\Delta V = 100$ fps	55
(b)	Retrograde $\Delta V = 300$ fps	56
(c)	Retrograde $\Delta V = 500$ fps	57
(d)	Retrograde $\Delta V = 700$ fps	58
15	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 200$ nautical miles and $h_p = 100$ nautical miles ^a	
(a)	Retrograde $\Delta V = 100$ fps	59
(b)	Retrograde $\Delta V = 300$ fps	60
(c)	Retrograde $\Delta V = 500$ fps	61
(d)	Retrograde $\Delta V = 700$ fps	62
16	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 250$ nautical miles and $h_p = 100$ nautical miles ^a	
(a)	Retrograde $\Delta V = 100$ fps	63
(b)	Retrograde $\Delta V = 300$ fps	64
(c)	Retrograde $\Delta V = 500$ fps	65
(d)	Retrograde $\Delta V = 700$ fps	66

17	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 400$ nautical miles and $h_p = 100$ nautical miles ^a	
(a)	Retrograde $\Delta V = 100$ fps	67
(b)	Retrograde $\Delta V = 300$ fps	68
(c)	Retrograde $\Delta V = 500$ fps	69
(d)	Retrograde $\Delta V = 700$ fps	70
18	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 140$ nautical miles and $h_p = 120$ nautical miles ^a	
(a)	Retrograde $\Delta V = 100$ fps	71
(b)	Retrograde $\Delta V = 300$ fps	72
(c)	Retrograde $\Delta V = 500$ fps	73
(d)	Retrograde $\Delta V = 700$ fps	74
19	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 150$ nautical miles and $h_p = 120$ nautical miles ^a	
(a)	Retrograde $\Delta V = 100$ fps	75
(b)	Retrograde $\Delta V = 300$ fps	76
(c)	Retrograde $\Delta V = 500$ fps	77
(c)	Retrograde $\Delta V = 700$ fps	78
20	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 200$ nautical miles and $h_p = 120$ nautical miles ^a	
(a)	Retrograde $\Delta V = 100$ fps	79
(b)	Retrograde $\Delta V = 300$ fps	80
(c)	Retrograde $\Delta V = 500$ fps	81
(d)	Retrograde $\Delta V = 700$ fps	82

21	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 250$ nautical miles and $h_p = 120$ nautical miles	
(a)	Retrograde $\Delta V = 100$ fps	83
(b)	Retrograde $\Delta V = 300$ fps	84
(c)	Retrograde $\Delta V = 500$ fps	85
(d)	Retrograde $\Delta V = 700$ fps	86
22	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 150$ nautical miles and $h_p = 140$ nautical miles	
(a)	Retrograde $\Delta V = 300$ fps	87
(b)	Retrograde $\Delta V = 500$ fps	88
(c)	Retrograde $\Delta V = 700$ fps	89
23	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 200$ nautical miles and $h_p = 140$ nautical miles	
(a)	Retrograde $\Delta V = 300$ fps	90
(b)	Retrograde $\Delta V = 500$ fps	91
(c)	Retrograde $\Delta V = 700$ fps	92
24	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 250$ nautical miles and $h_p = 140$ nautical miles	
(a)	Retrograde $\Delta V = 300$ fps	93
(b)	Retrograde $\Delta V = 500$ fps	94
(c)	Retrograde $\Delta V = 700$ fps	95

25	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 400$ nautical miles and $h_p = 140$ nautical miles	
(a)	Retrograde $\Delta V = 300$ fps	96
(b)	Retrograde $\Delta V = 500$ fps	97
(c)	Retrograde $\Delta V = 700$ fps	98
26	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 180$ nautical miles and $h_p = 153$ nautical miles	
(a)	Retrograde $\Delta V = 300$ fps	99
(b)	Retrograde $\Delta V = 500$ fps	100
(c)	Retrograde $\Delta V = 700$ fps	101
27	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 200$ nautical miles and $h_p = 153$ nautical miles	
(a)	Retrograde $\Delta V = 300$ fps	102
(b)	Retrograde $\Delta V = 500$ fps	103
(c)	Retrograde $\Delta V = 700$ fps	104
28	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 250$ nautical miles and $h_p = 153$ nautical miles	
(a)	Retrograde $\Delta V = 300$ fps	105
(b)	Retrograde $\Delta V = 500$ fps	107
(c)	Retrograde $\Delta V = 700$ fps	108
29	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 400$ nautical miles and $h_p = 153$ nautical miles	

Figure

Page

	(a) Retrograde $\Delta V = 300$ fps	108
	(b) Retrograde $\Delta V = 500$ fps	109
	(c) Retrograde $\Delta V = 700$ fps	110
30	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 180$ nautical miles and $h_p = 160$ nautical miles ^a	
	(a) Retrograde $\Delta V = 300$ fps	111
	(b) Retrograde $\Delta V = 500$ fps	112
	(c) Retrograde $\Delta V = 700$ fps	113
31	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 200$ nautical miles and $h_p = 160$ nautical miles ^a	
	(a) Retrograde $\Delta V = 300$ fps	114
	(b) Retrograde $\Delta V = 500$ fps	115
	(c) Retrograde $\Delta V = 700$ fps	116
32	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 250$ nautical miles and $h_p = 160$ nautical miles ^a	
	(a) Retrograde $\Delta V = 300$ fps	117
	(b) Retrograde $\Delta V = 500$ fps	118
	(c) Retrograde $\Delta V = 700$ fps	119
33	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 400$ nautical miles and $h_p = 160$ nautical miles ^a	
	(a) Retrograde $\Delta V = 300$ fps	120
	(b) Retrograde $\Delta V = 500$ fps	121
	(c) Retrograde $\Delta V = 700$ fps	122

34	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 200$ nautical miles and $h_p = 180$ nautical miles ^a	
(a)	Retrograde $\Delta V = 300$ fps	123
(b)	Retrograde $\Delta V = 500$ fps	124
(c)	Retrograde $\Delta V = 700$ fps	125
35	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 250$ nautical miles and $h_p = 180$ nautical miles ^a	
(a)	Retrograde $\Delta V = 300$ fps	126
(b)	Retrograde $\Delta V = 500$ fps	127
(c)	Retrograde $\Delta V = 700$ fps	128
36	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 300$ nautical miles and $h_p = 180$ nautical miles ^a	
(a)	Retrograde $\Delta V = 300$ fps	129
(b)	Retrograde $\Delta V = 500$ fps	130
(c)	Retrograde $\Delta V = 700$ fps	131
37	Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 400$ nautical miles and $h_p = 180$ nautical miles ^a	
(a)	Retrograde $\Delta V = 300$ fps	132
(b)	Retrograde $\Delta V = 500$ fps	133
(c)	Retrograde $\Delta V = 700$ fps	134

A PARAMETRIC STUDY OF CENTRAL ANGLE OF TRAVEL AND TIME FOR REENTRY FROM NEAR-EARTH ORBITS

By William R. Pruett

SUMMARY AND INTRODUCTION

This paper is a continuation of reference 1, "General Parametric Study for Near-Earth Orbits," by Frank J. Suler. Contained in this report are the orbit-referenced central angle of travel from retrofire to 400 000 ft and the time from retrofire to 400 000 ft as functions of true anomaly of retrofire. The same ranges of retrograde pitch angles, retrograde ΔV 's, and elliptical orbits are used in this report as were used in reference 1. Since reference 1 presents reentry velocity and flight-path angle at 400 000 ft, this document and reference 1 should be used together to obtain a more valuable picture of reentry conditions.

For additional information concerning near-earth orbits, see reference 2.

MATHEMATICAL MODEL

Keplerian equations, a spherical rotating earth, and instantaneous velocity changes were used in this study. The solutions were obtained from the general elliptical orbit and reentry program, EO42. Beta angles are measured positive clockwise from the local horizontal. For a geometric representation of the orbit parameters, see paragraph 2.2 of reference 1.

DISCUSSION OF RESULTS

The figures presented were plotted by an SC 4020 microfilm plotter. The plot program used (ref. 3) converts binary x-y coordinates generated by an IBM 7094 computer into 4020 plot tapes.

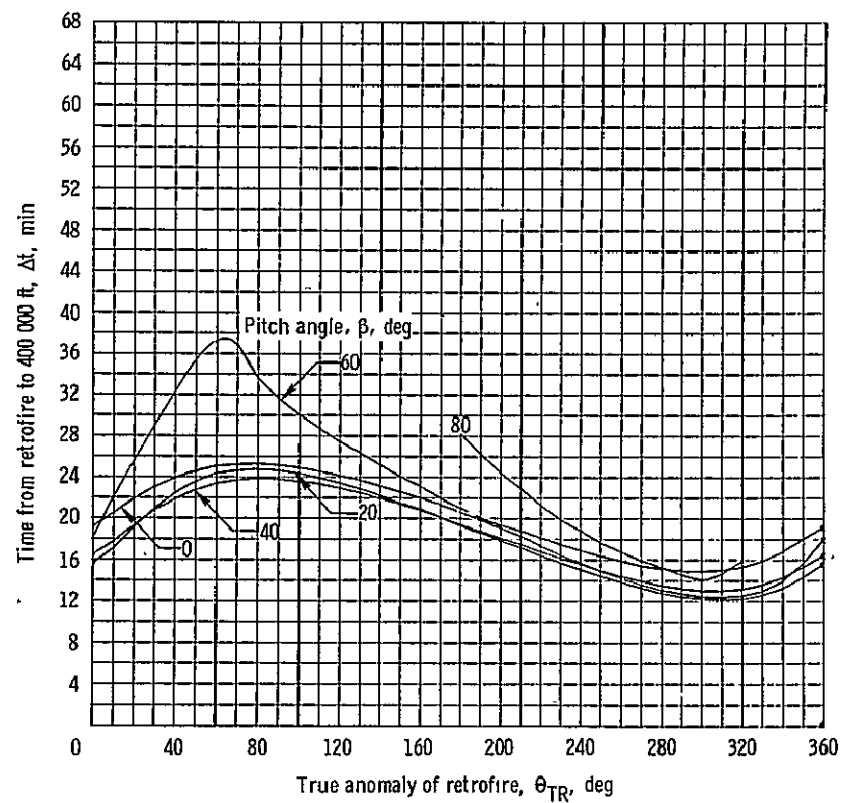
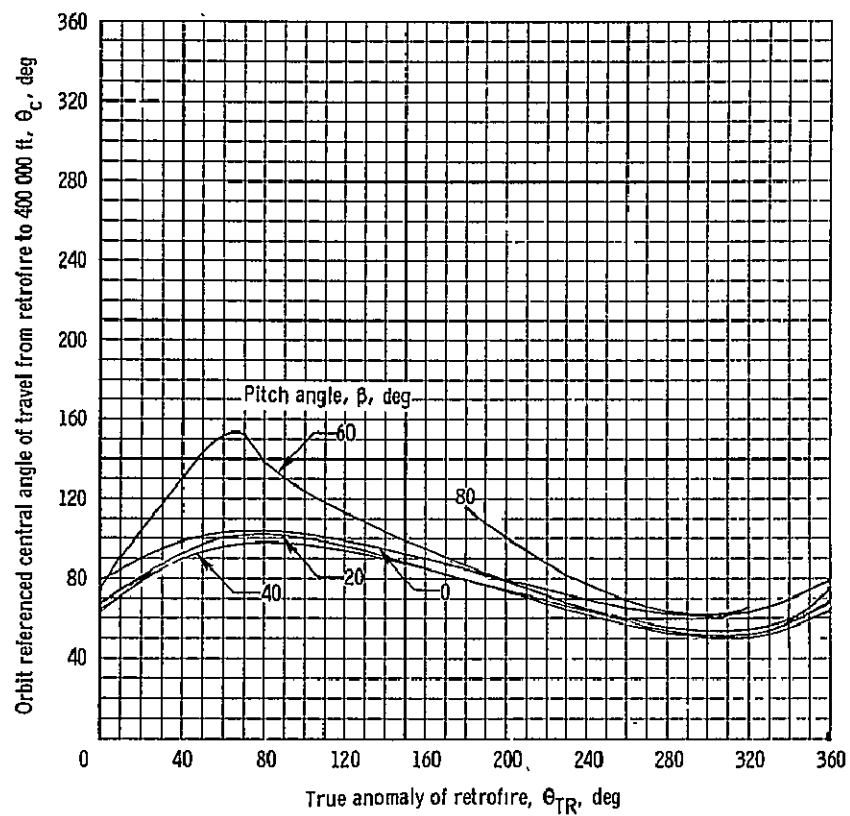
The curves plotted in the figures are not extremely smooth, for two main reasons.

First, the true anomaly increment used was ten degrees; therefore, a computed point is plotted every ten degrees. These points were simply connected by straight lines, and no attempt was made to fit a curve to them. Smoother curves could be obtained by using a smaller computing interval, but this would greatly increase the computing time. This could not be justified since the errors encountered using a 10° true anomaly increment were not significant when compared to other computation errors.

Second, errors existed because of the program's characteristics. In the program, true anomaly and time are calculated from a computed value of flight-path angle. For the very slightly elliptical orbits which were considered, flight-path angles seldom exceeded $\pm 1^\circ$, and calculations of true anomaly and time based on these angles were not extremely accurate. Some errors were found to be near $\pm 4^\circ$ in true anomaly and ± 60 seconds in time, but these errors were seldom experienced. The average error in computation, for the reason stated, was about $\pm .5^\circ$ in true anomaly and ± 10 seconds in time.

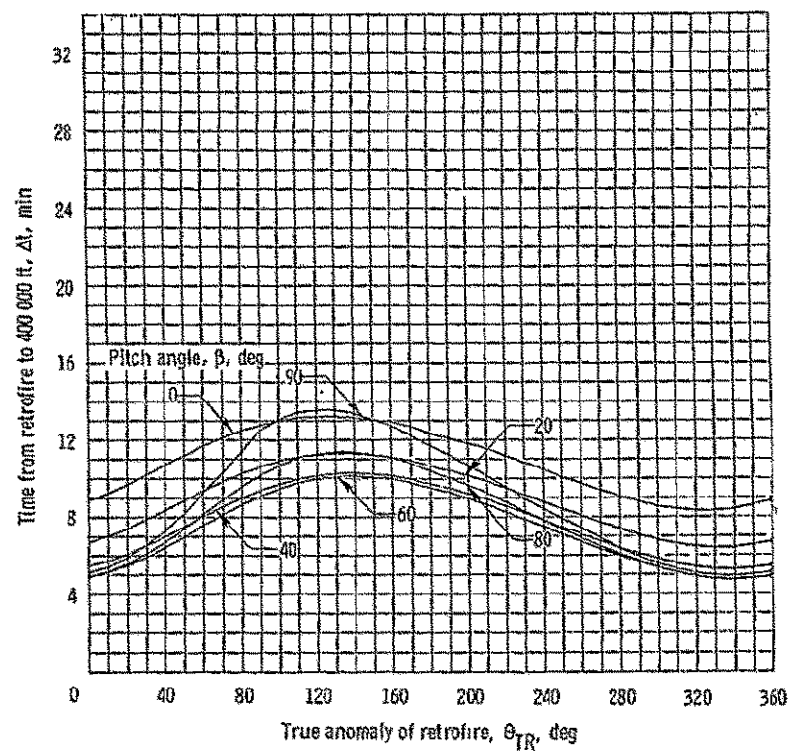
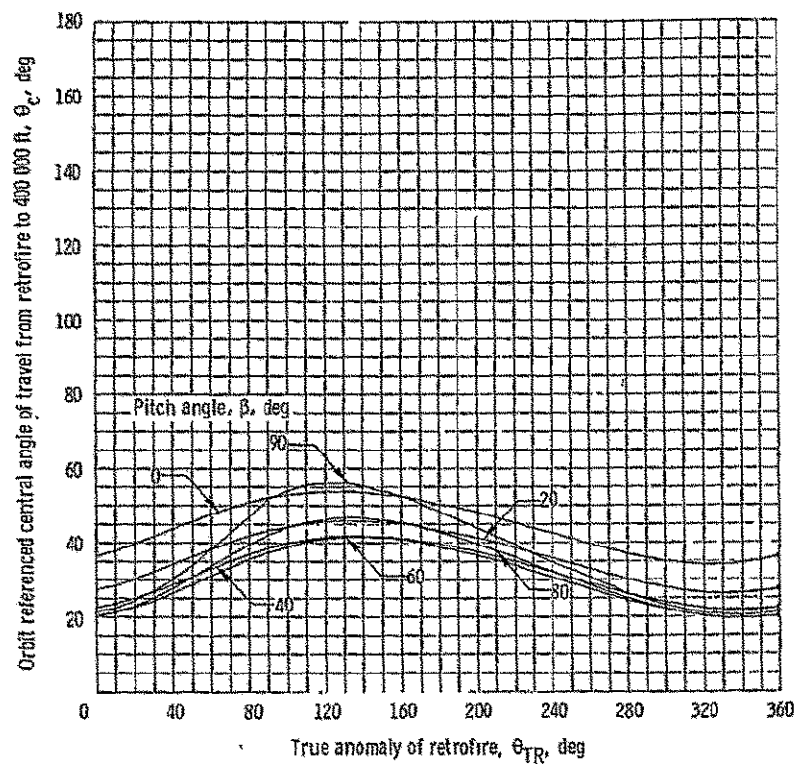
These errors were obtained by simply interpreting inconsistencies in the plots and are not meant to be highly accurate. In fact, this entire explanation of the figures is intended only to explain why the figures are not extremely smooth, not to describe how large the inaccuracies are. However, for the general mission planning for which this paper is intended, the data presented is felt to be quite satisfactory.

Each of the figures presents both time from retrofire to 400 000 ft and orbit-referenced central angle of travel from retrofire to 400 000 ft as functions of true anomaly of retrofire. Pitch angles of 0° , 20° , 40° , 60° , 80° , and 90° were used for each plot, and retrograde ΔV 's of 100 fps, 300 fps, 500 fps and 700 fps were used for each figure. If one or more of these parameters are not presented in a figure, reentry was not possible under those conditions.



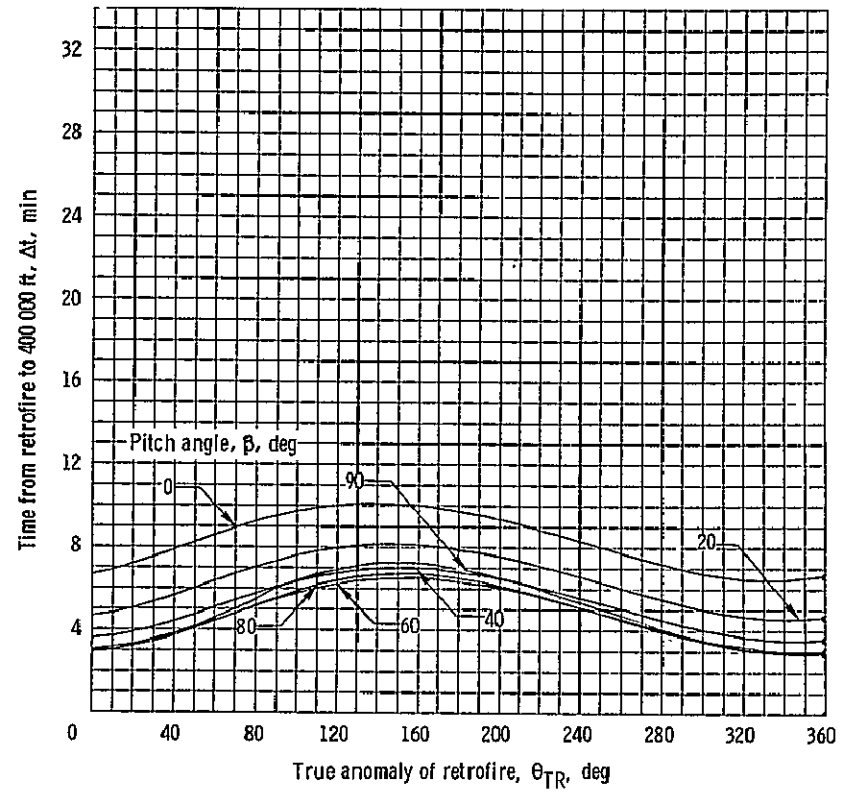
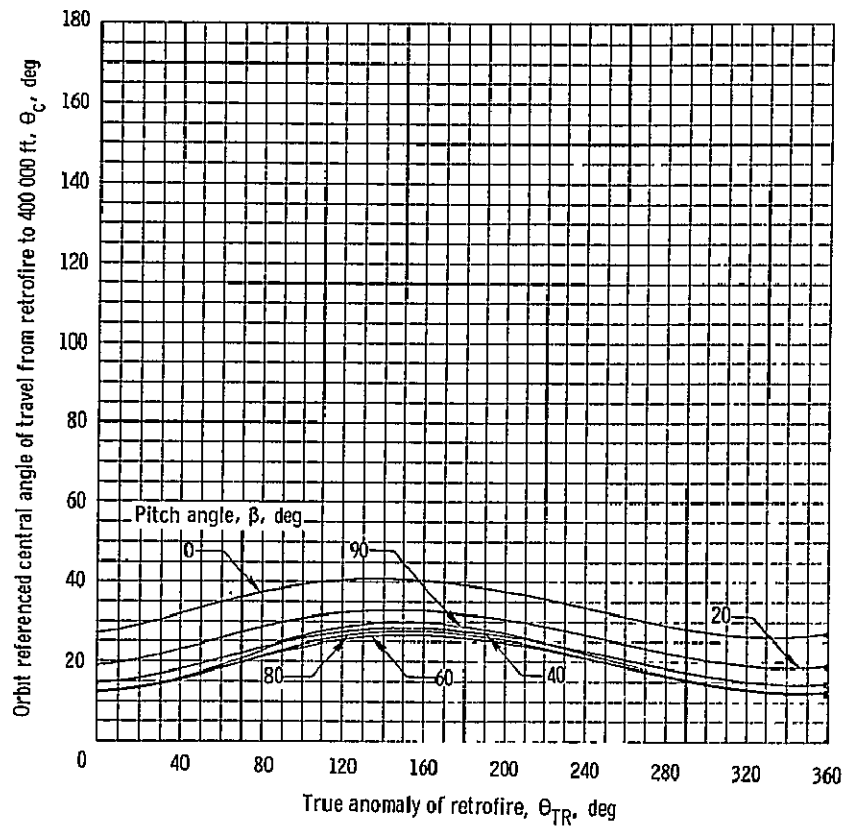
(a) Retrograde $\Delta V = 100$ fps.

Figure 1. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 100$ nautical miles and $h_p = 80$ nautical miles.



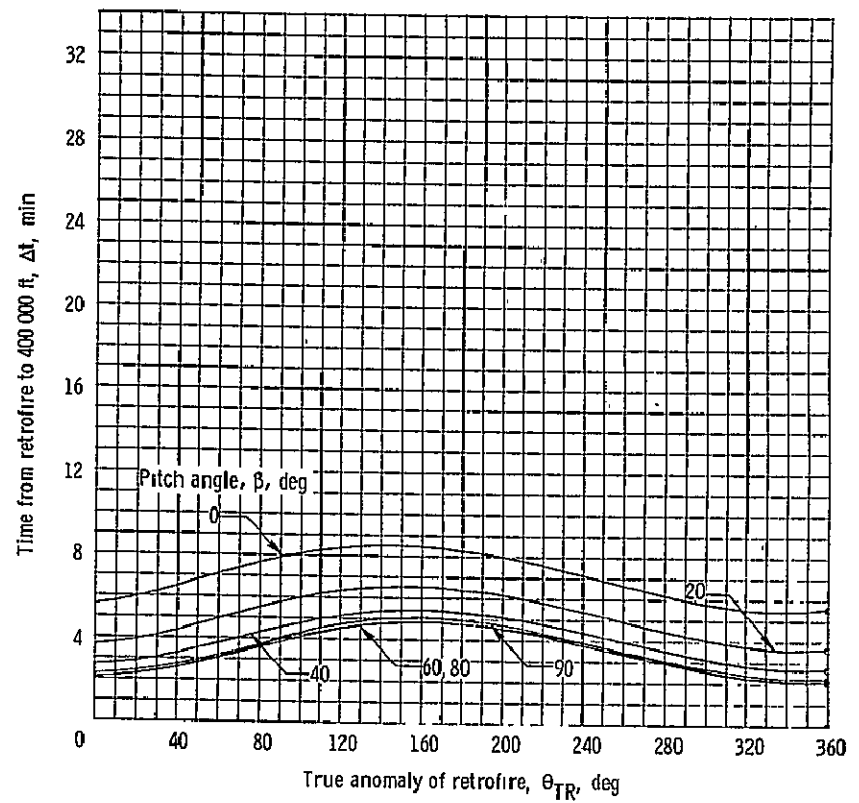
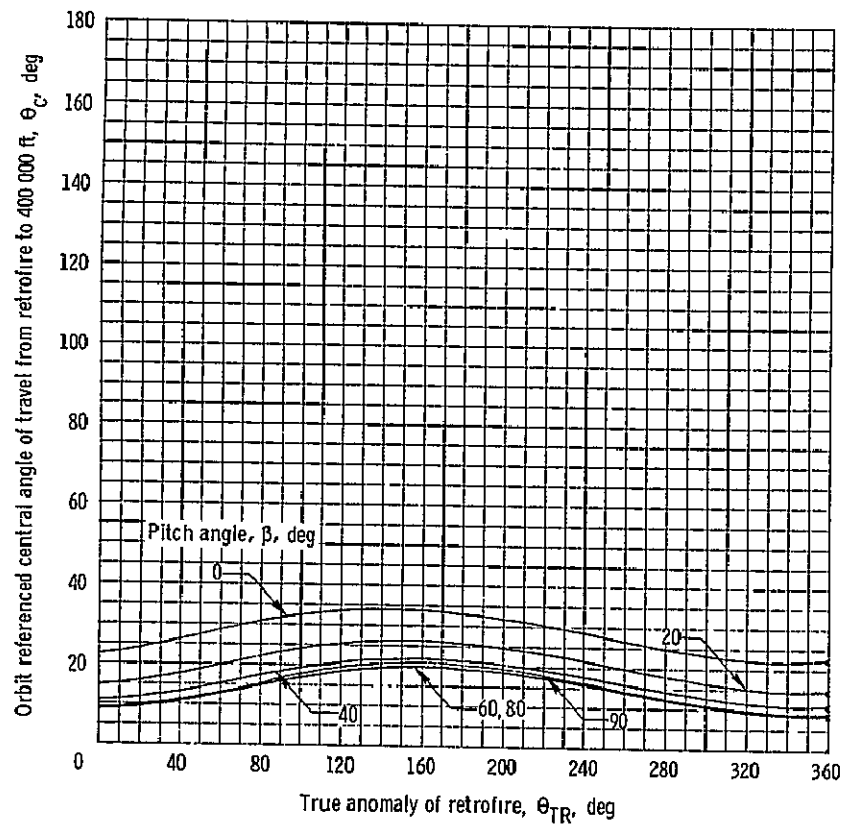
(b) Retrograde $\Delta V = 300$ fps.

Figure 1. - Continued.



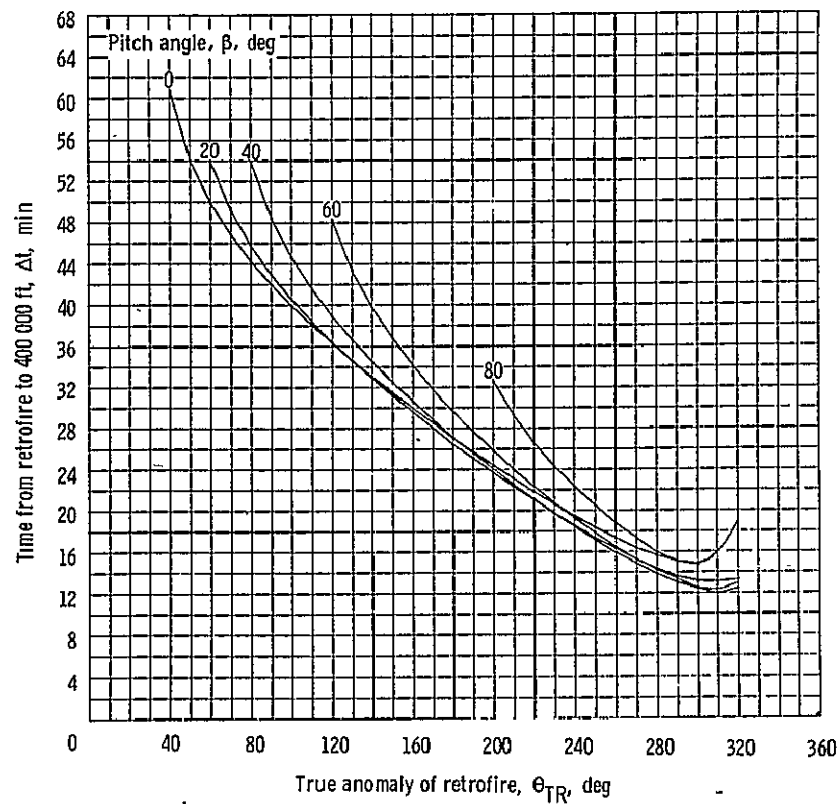
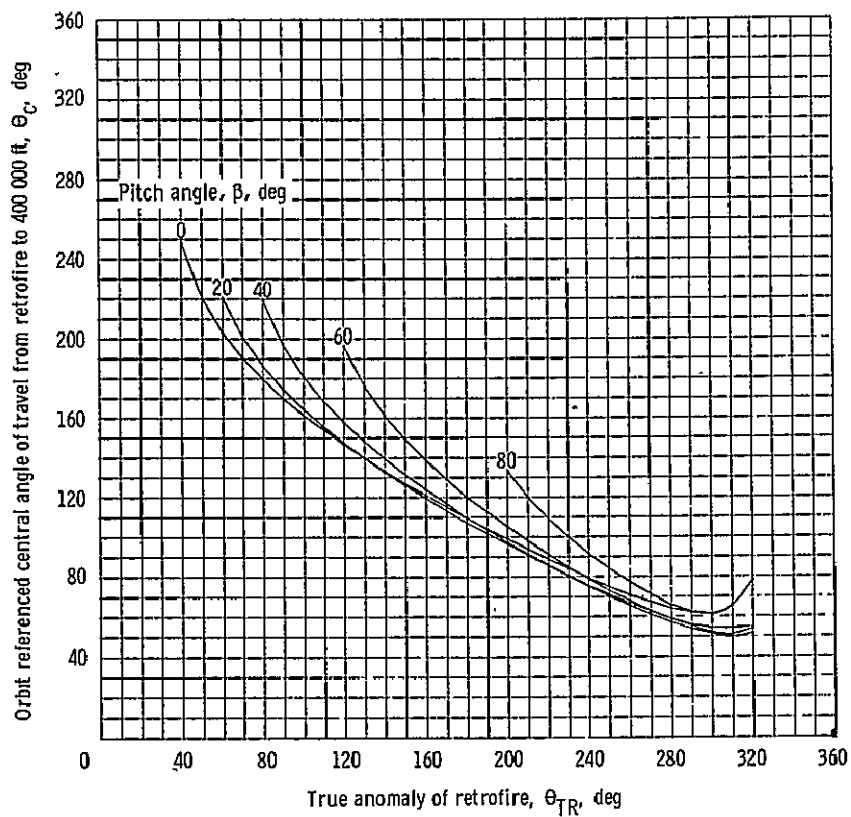
(c) Retrograde $\Delta V = 500$ fps.

Figure 1. - Continued.



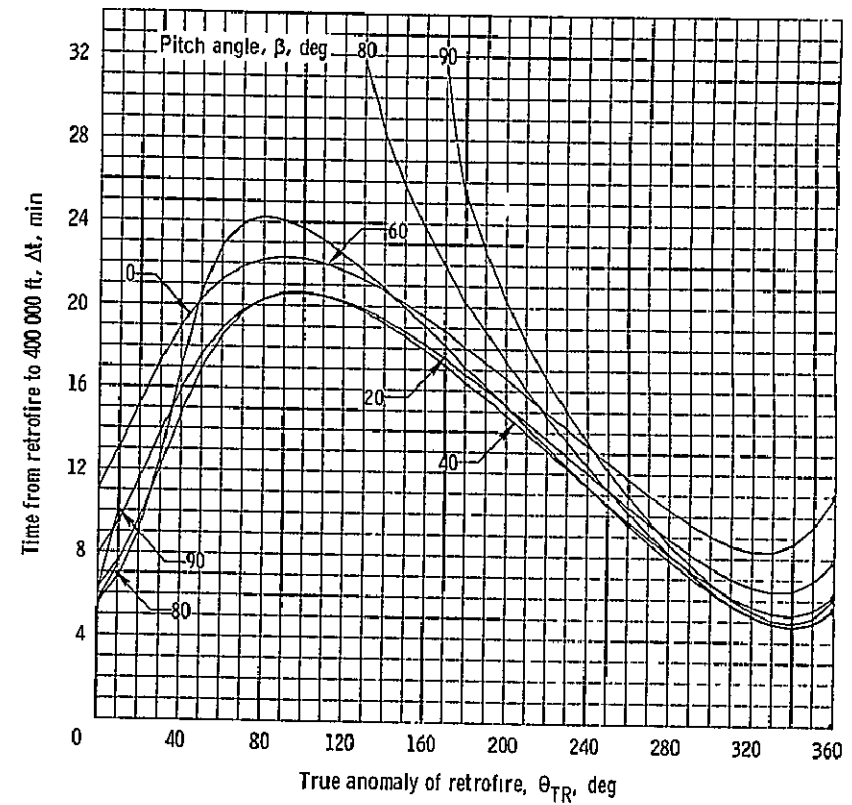
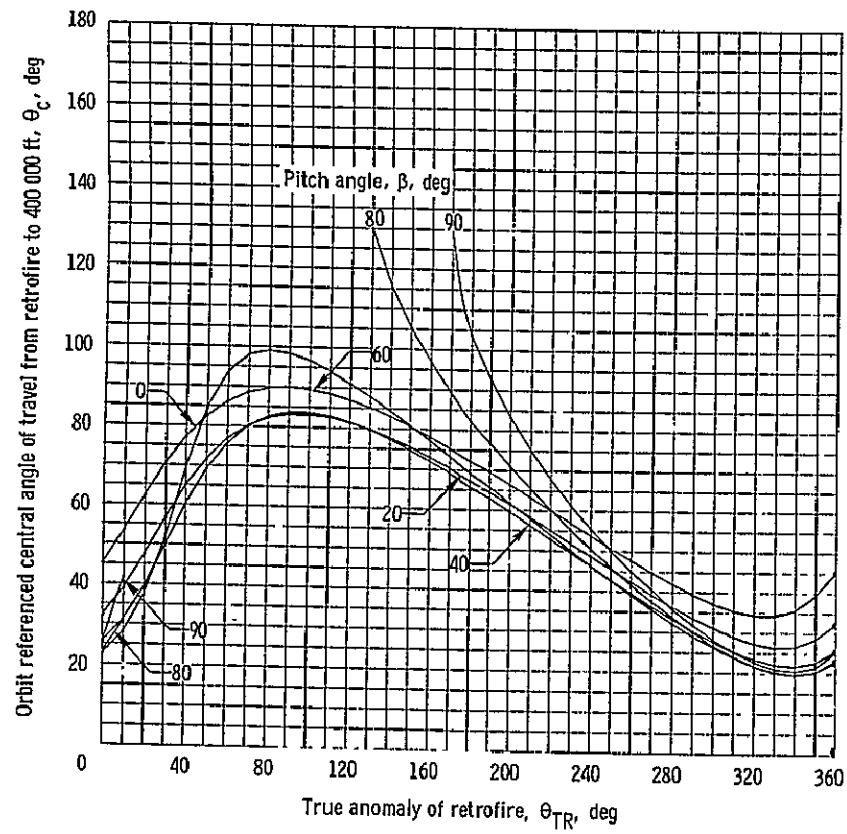
(d) Retrograde $\Delta V = 700$ fps.

Figure 1. - Concluded.



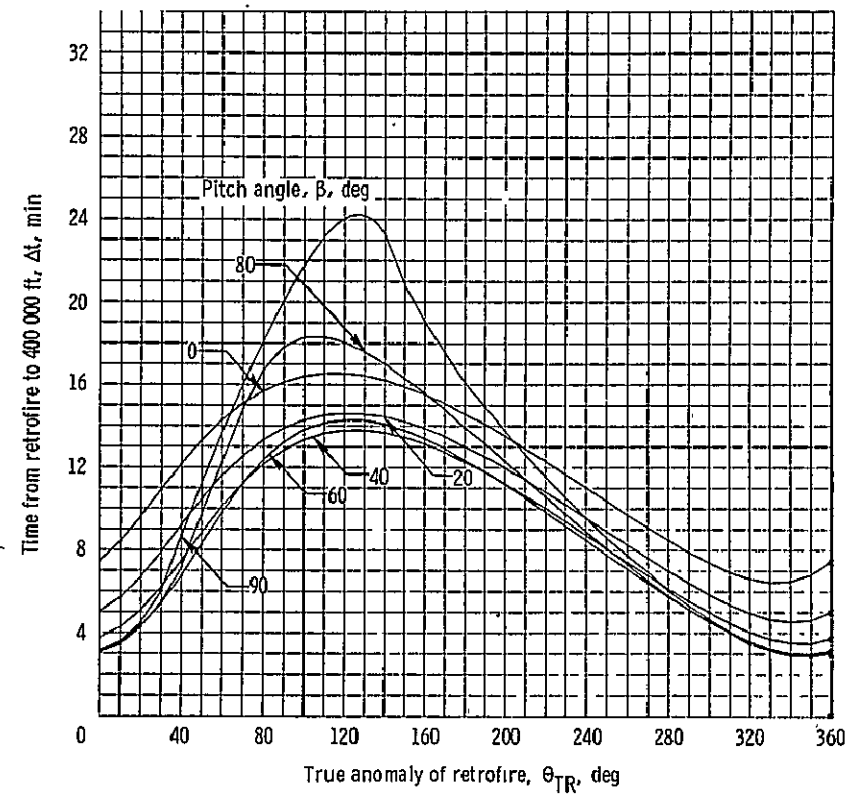
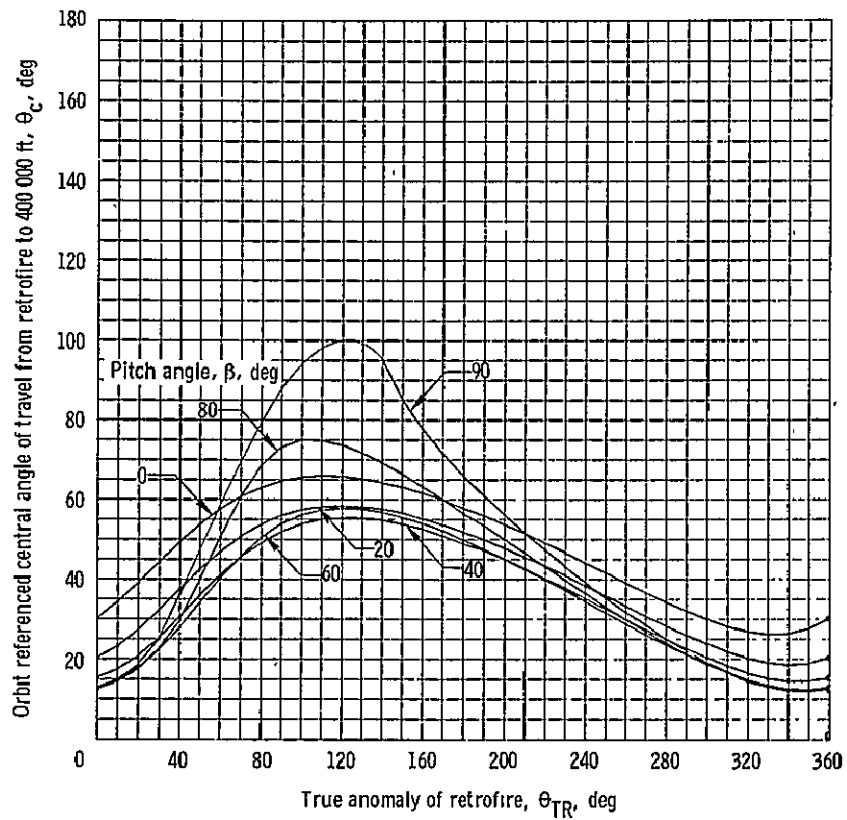
(a) Retrograde $\Delta V = 100$ fps.

Figure 2. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 150$ nautical miles and $h_p = 80$ nautical miles.



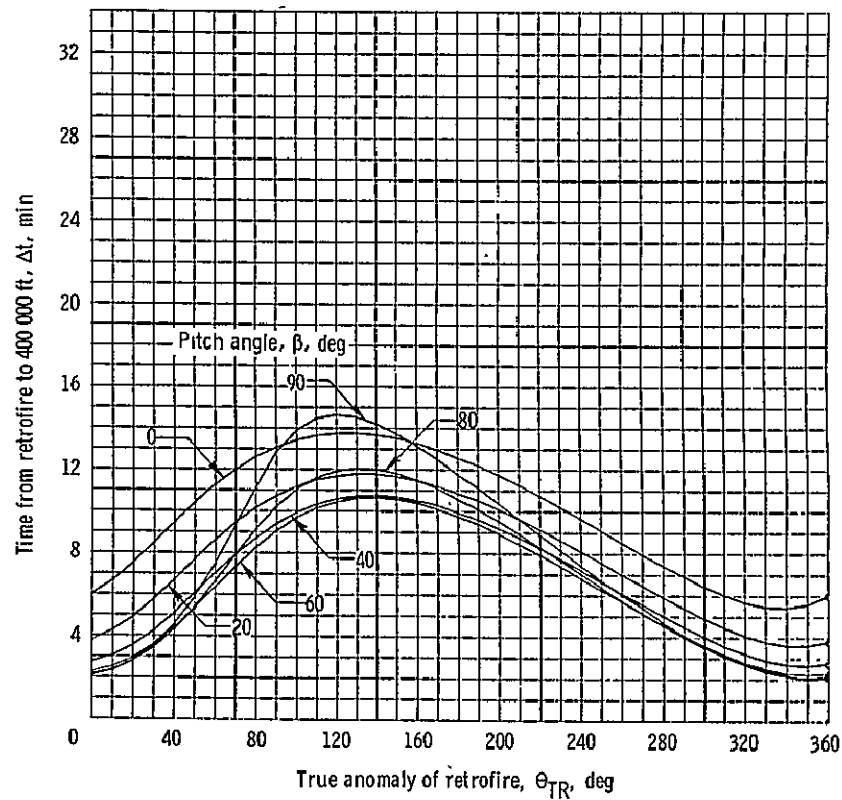
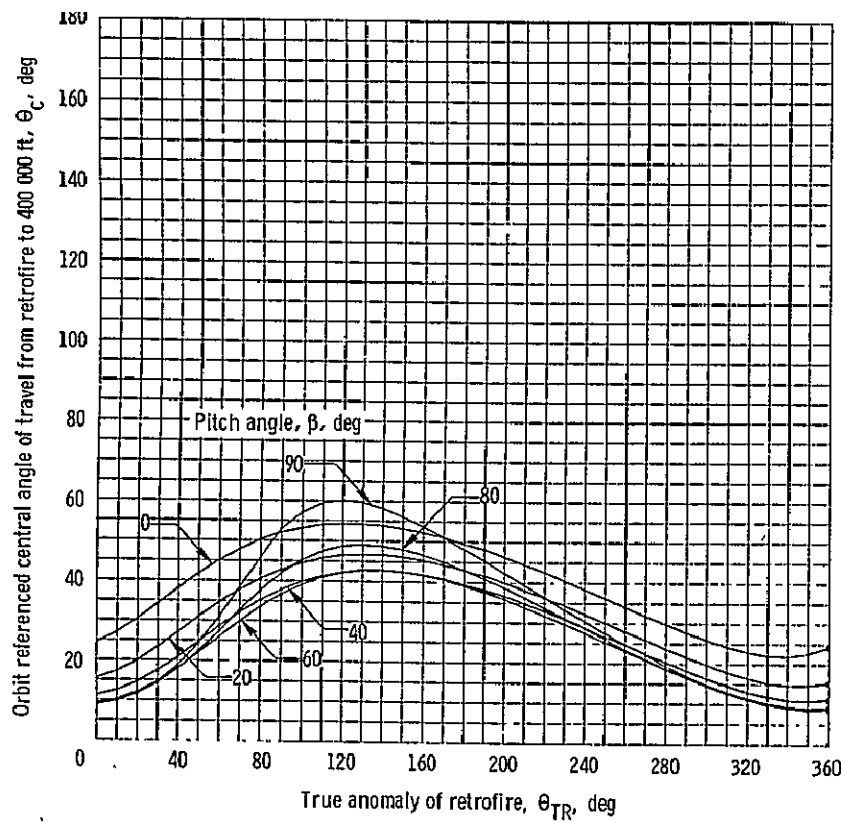
(b) Retrograde $\Delta V = 300$ fps.

Figure 2. - Continued.



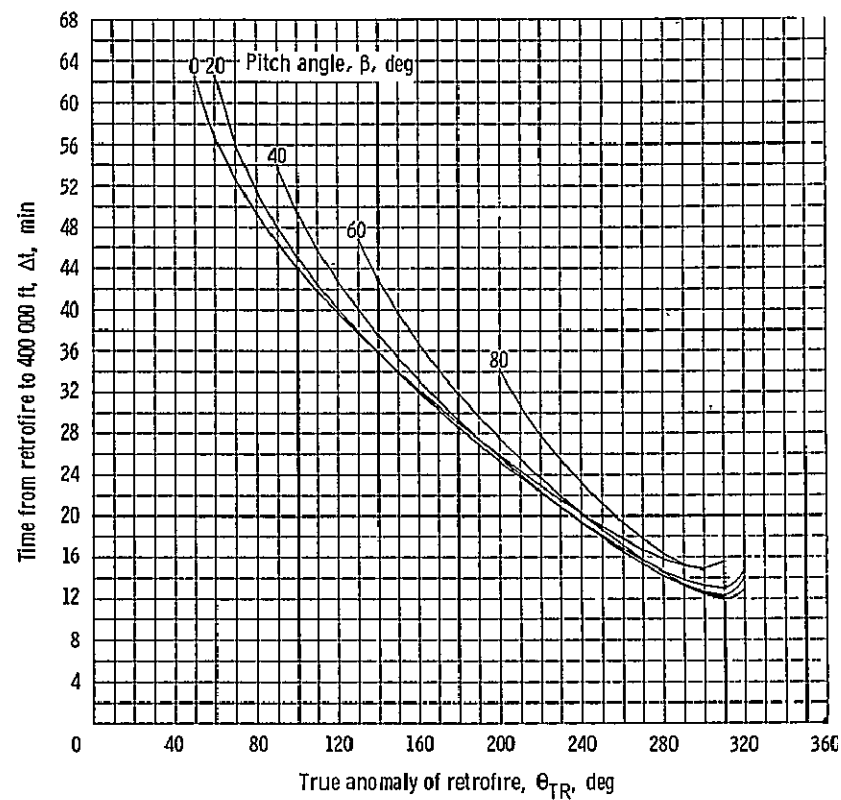
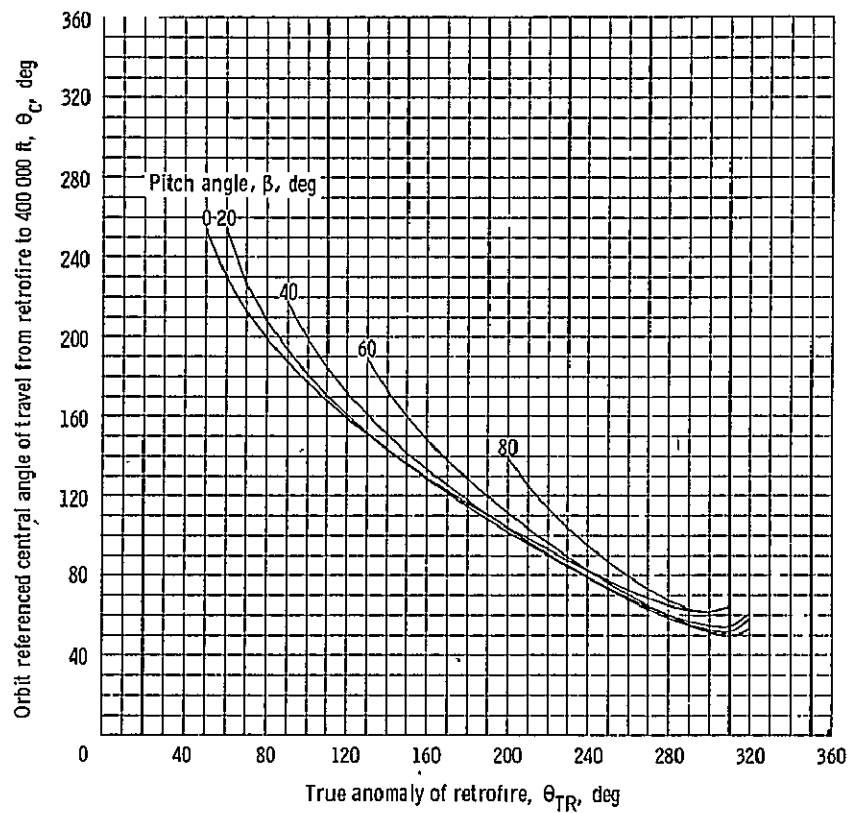
(c) Retrograde $\Delta V = 500$ fps.

Figure 2. - Continued.



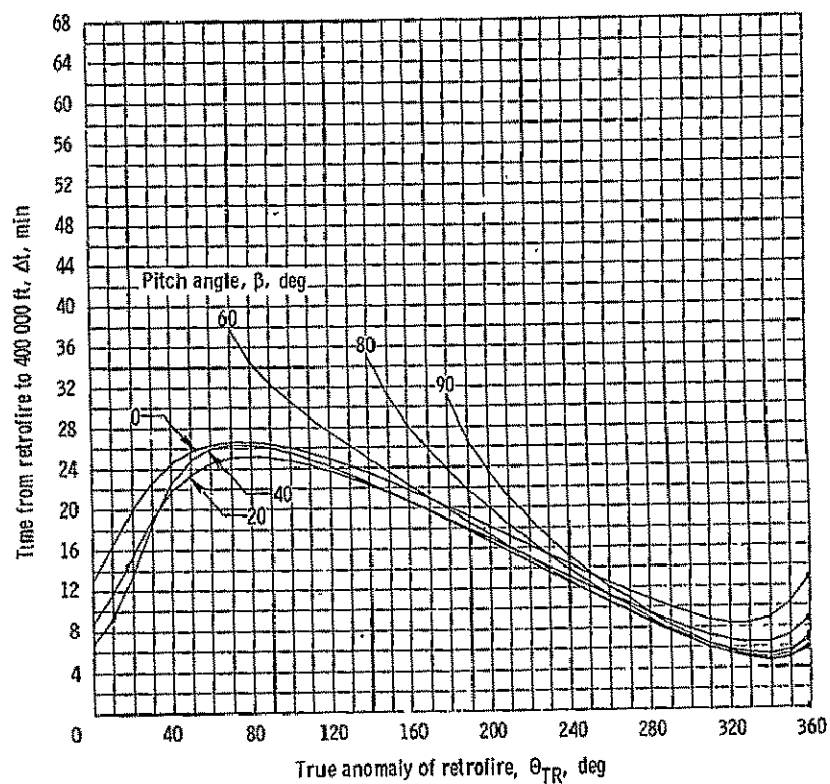
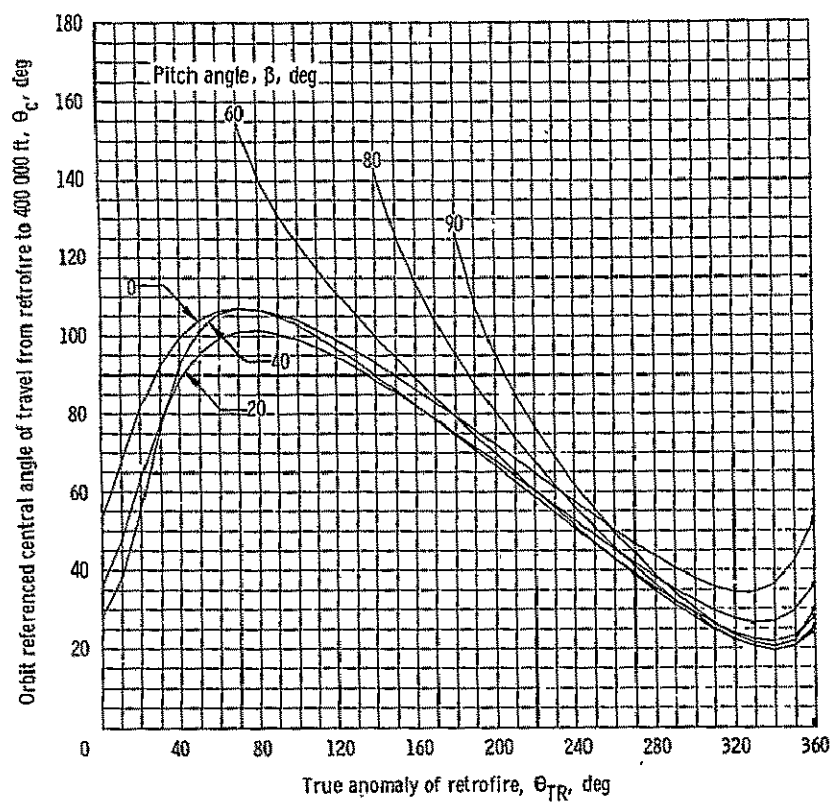
(d) Retrograde $\Delta V = 700$ fps.

Figure 2. - Concluded.



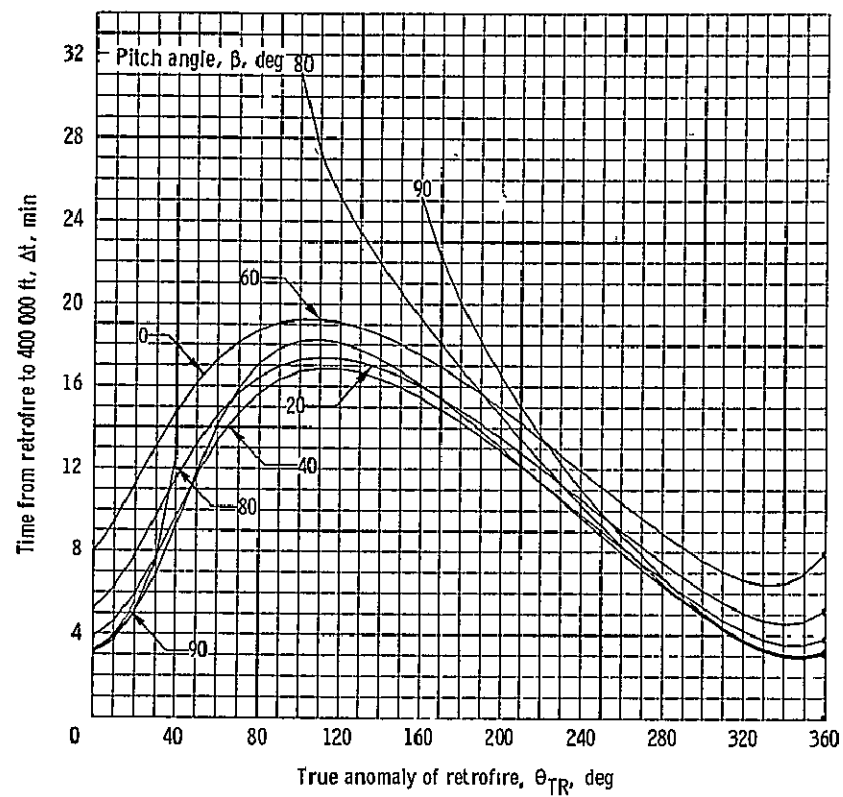
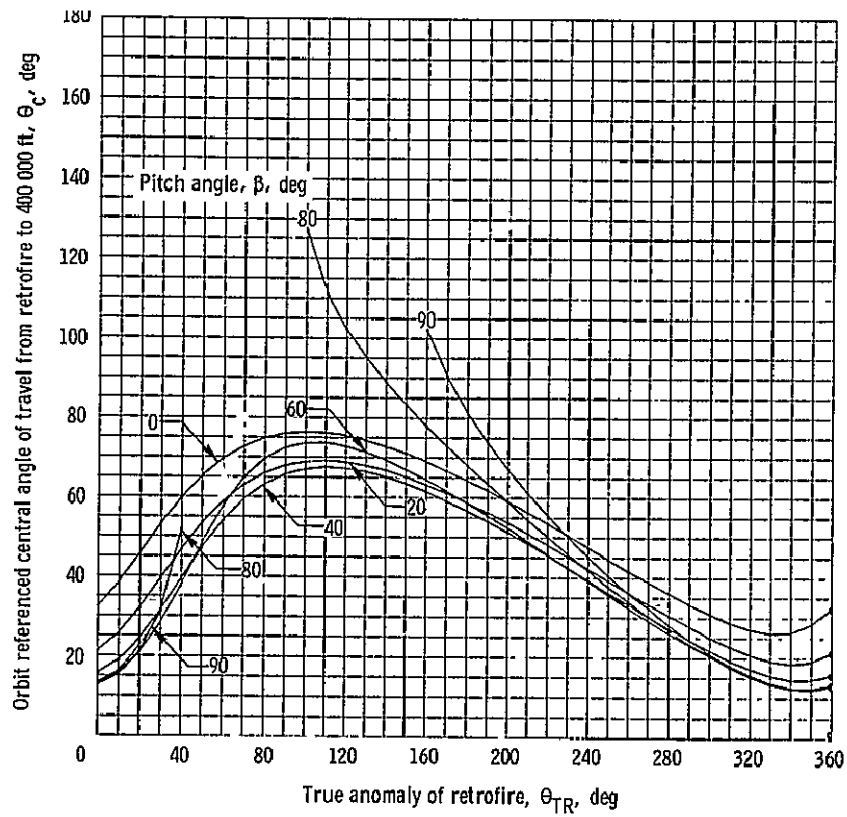
(a) Retrograde $\Delta V = 100$ fps.

Figure 3. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 175$ nautical miles and $h_p = 80$ nautical miles.



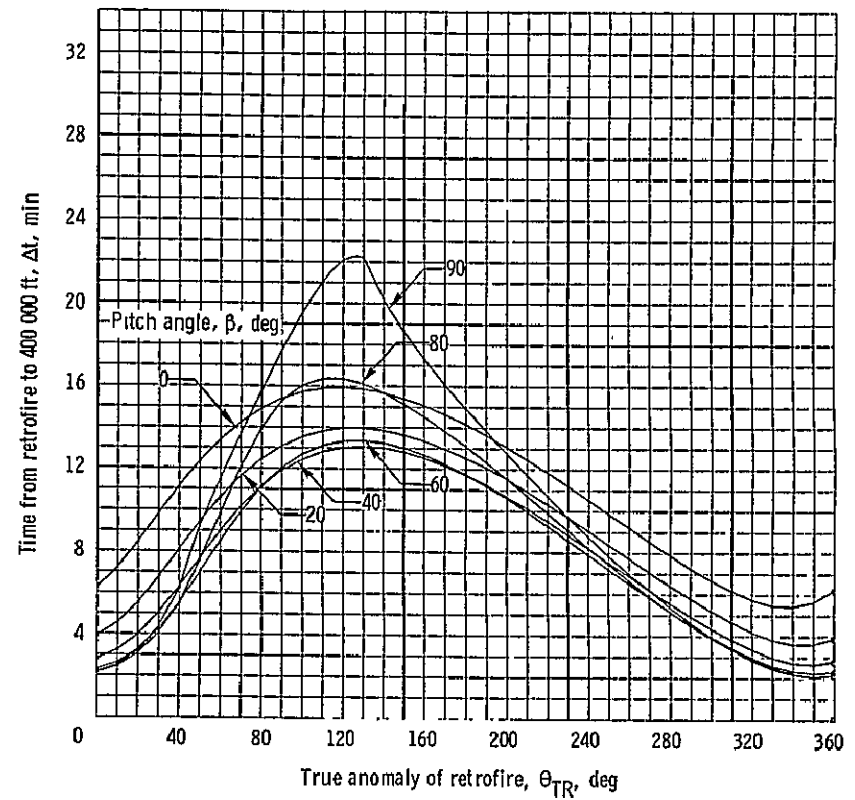
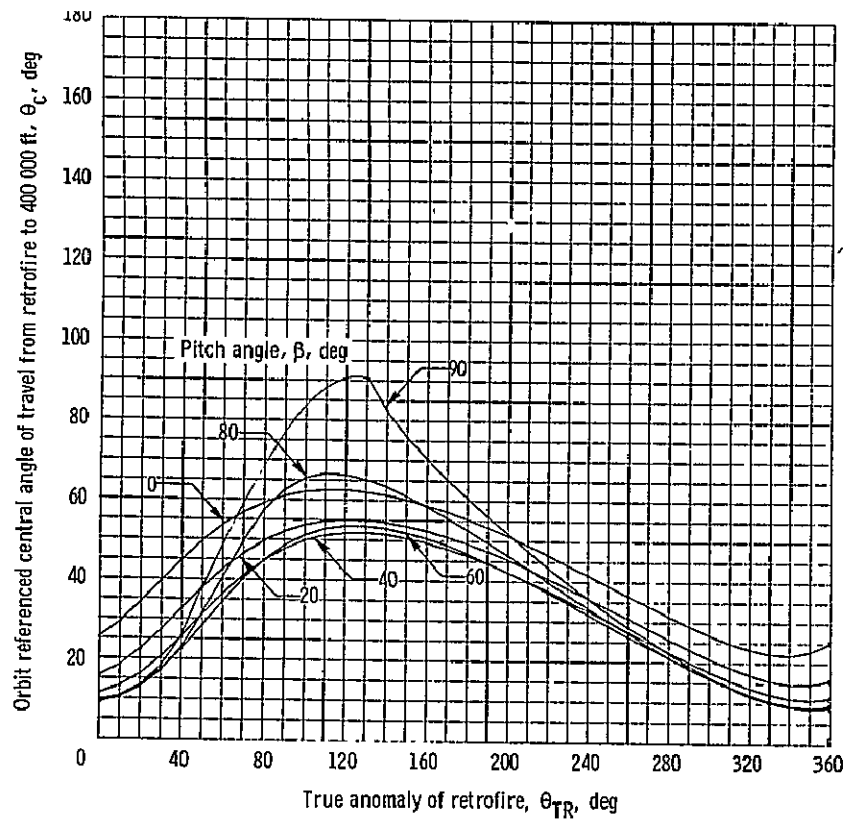
(b) Retrograde $\Delta V = 300$ fps.

Figure 3. - Continued.



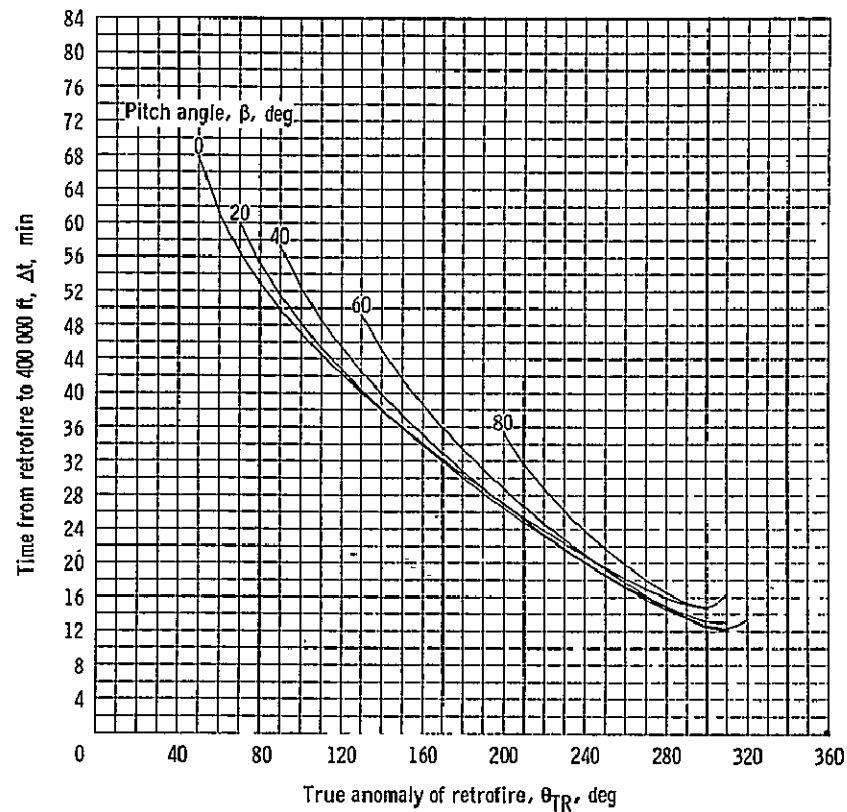
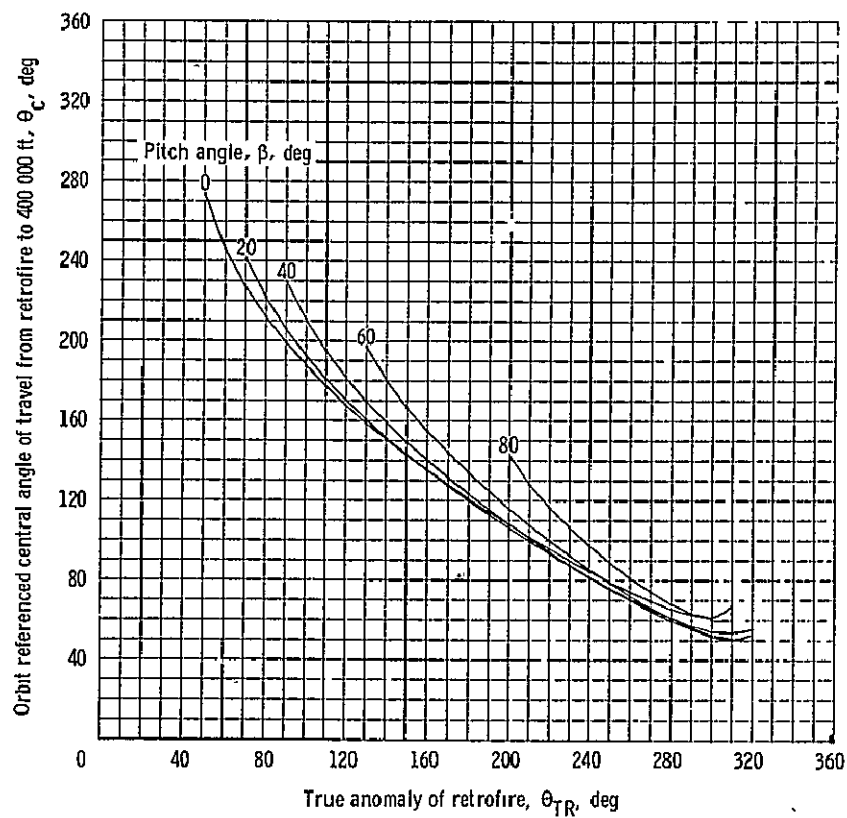
(c) Retrograde $\Delta V = 500$ fps.

Figure 3. - Continued.



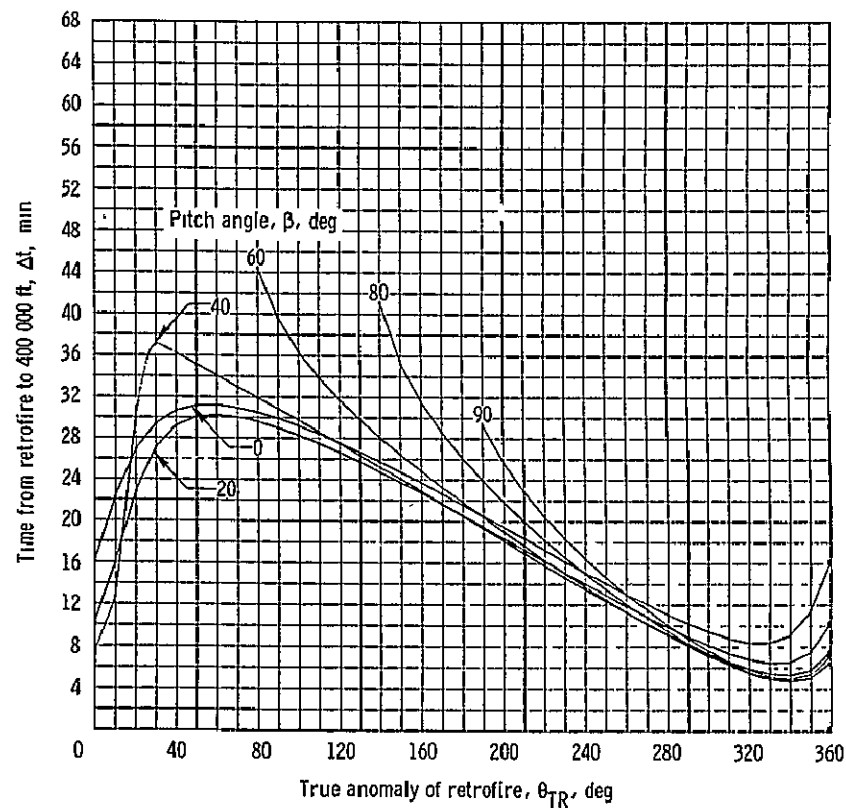
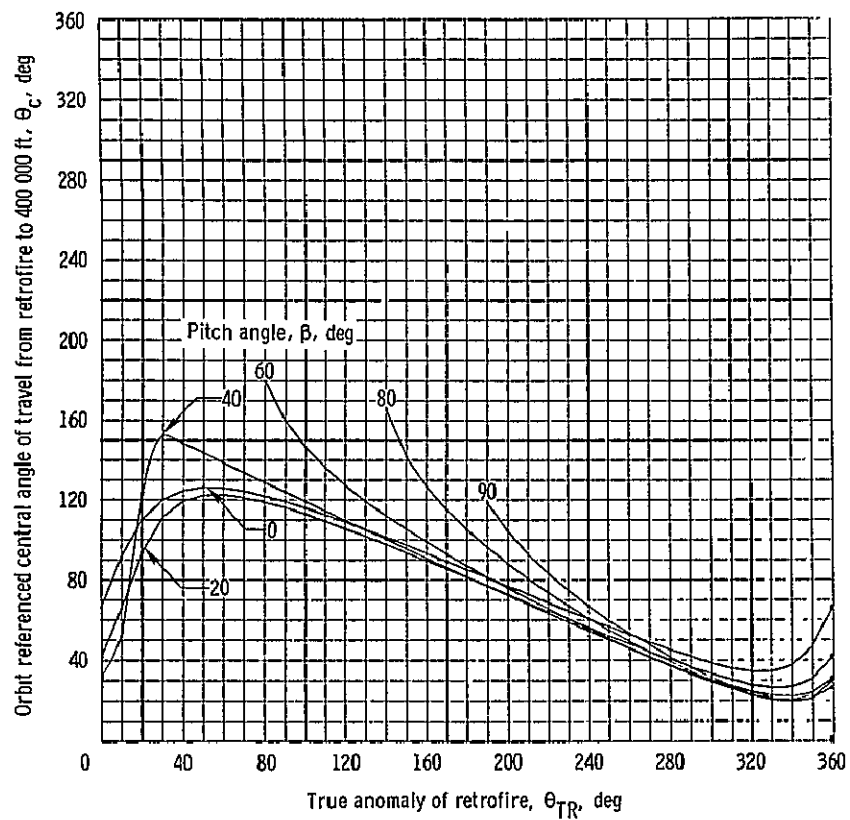
(d) Retrograde $\Delta V = 700$ fps.

Figure 3. - Concluded.

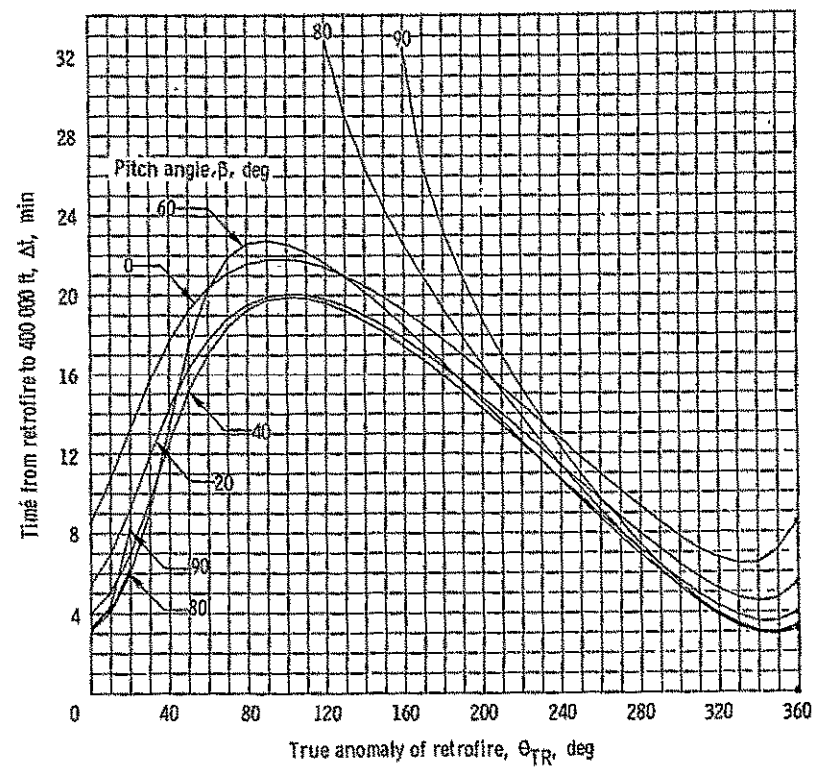
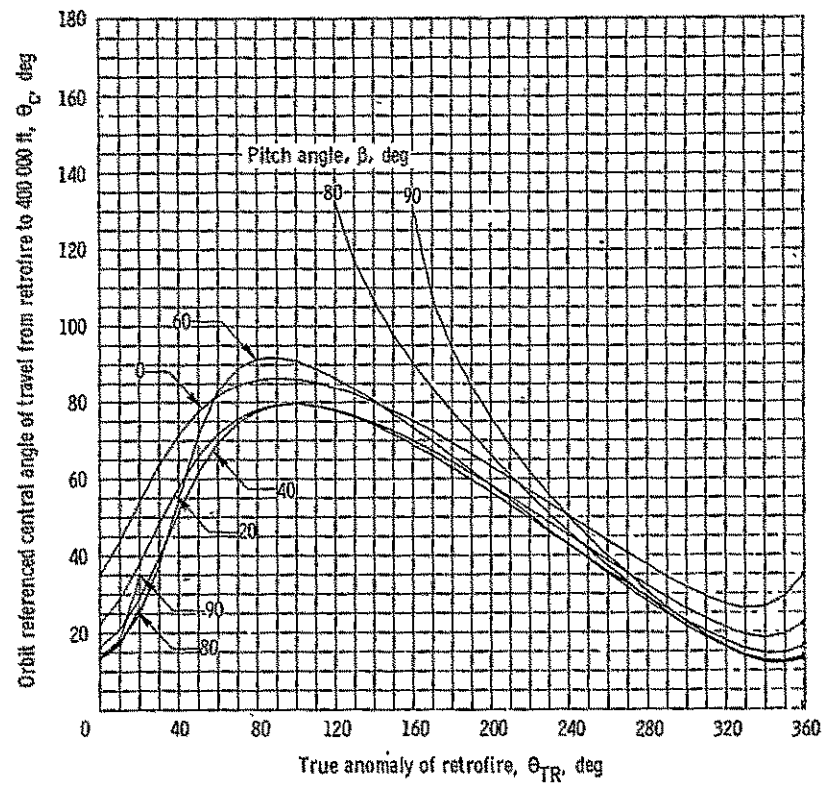


(a) Retrograde $\Delta V = 100$ fps.

Figure 4. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 200$ nautical miles and $h_p = 80$ nautical miles.

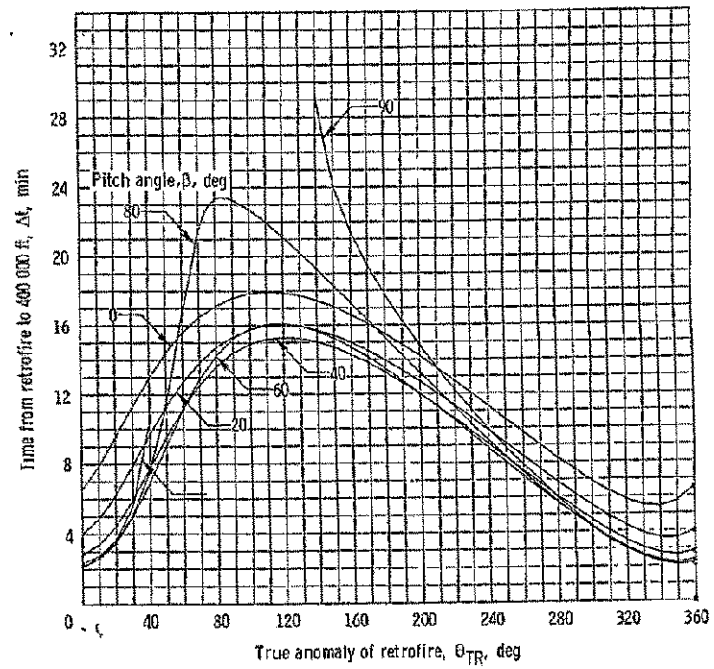
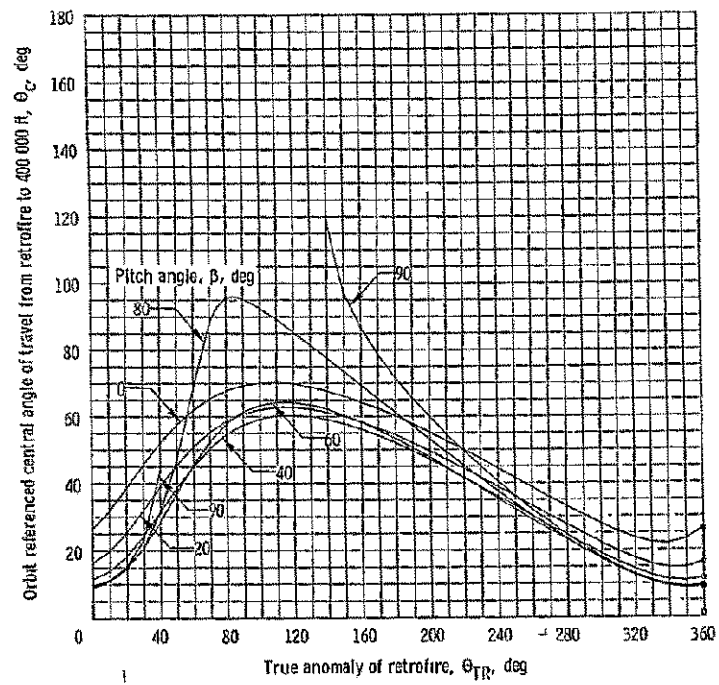


(b) Retrograde $\Delta V = 300$ fps.



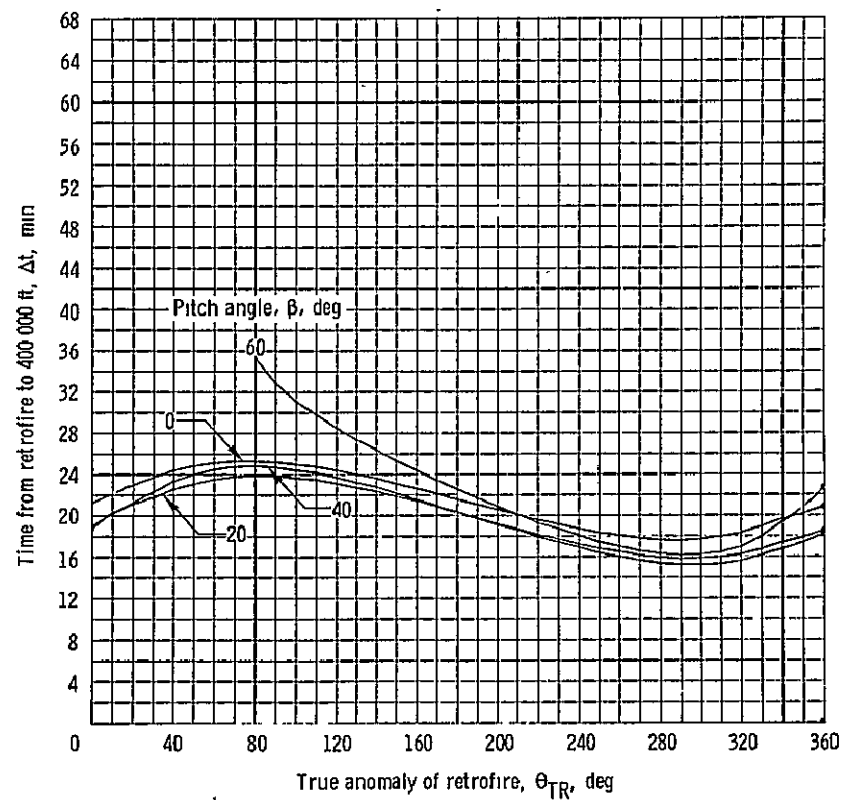
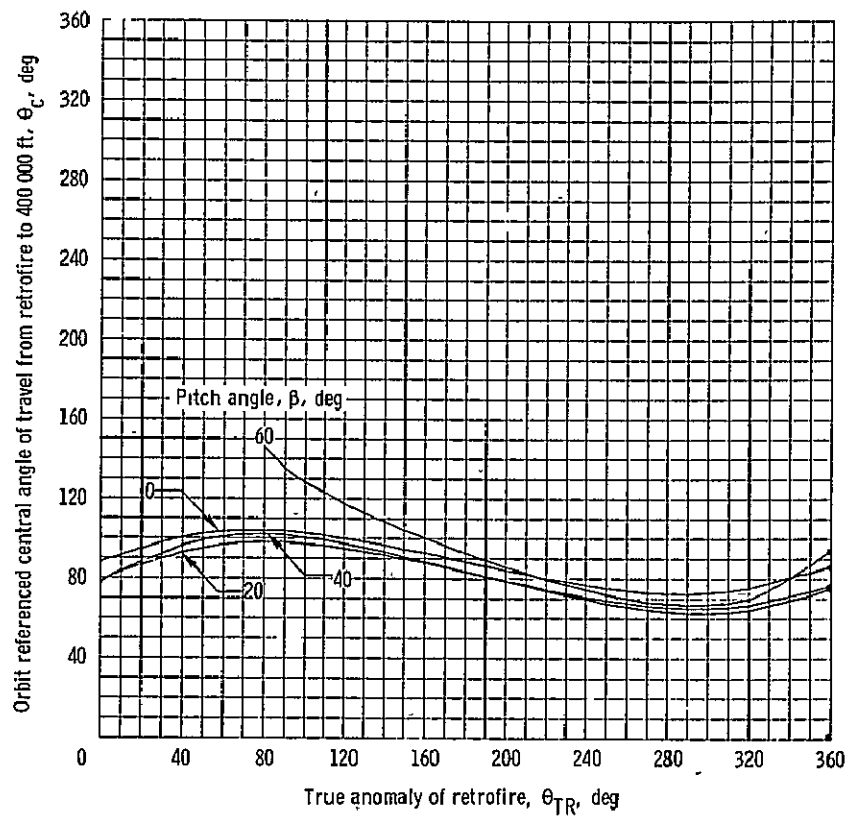
(c) Retrograde $\Delta V = 500$ fps.

Figure 4. - Continued.



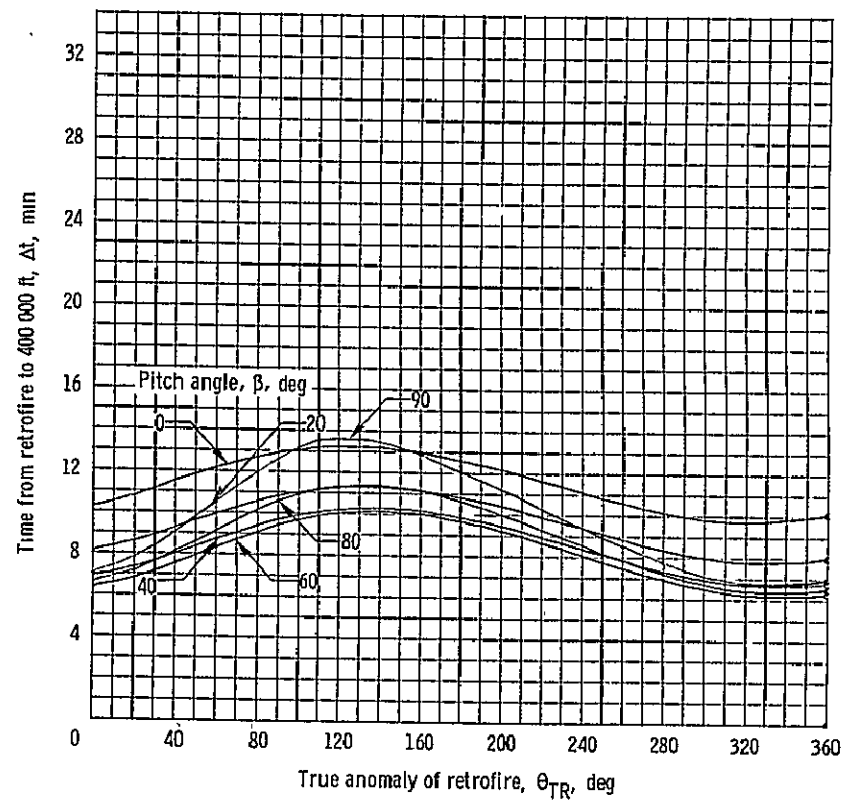
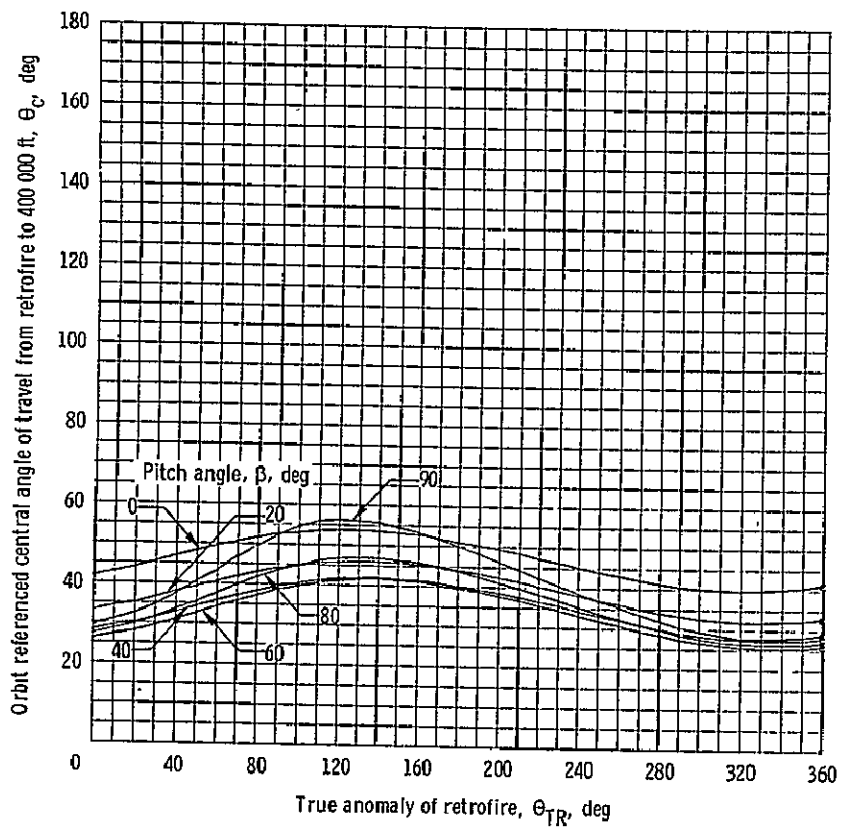
(d) Retrograde $\Delta V = 700$ fps.

Figure 4. - Concluded.



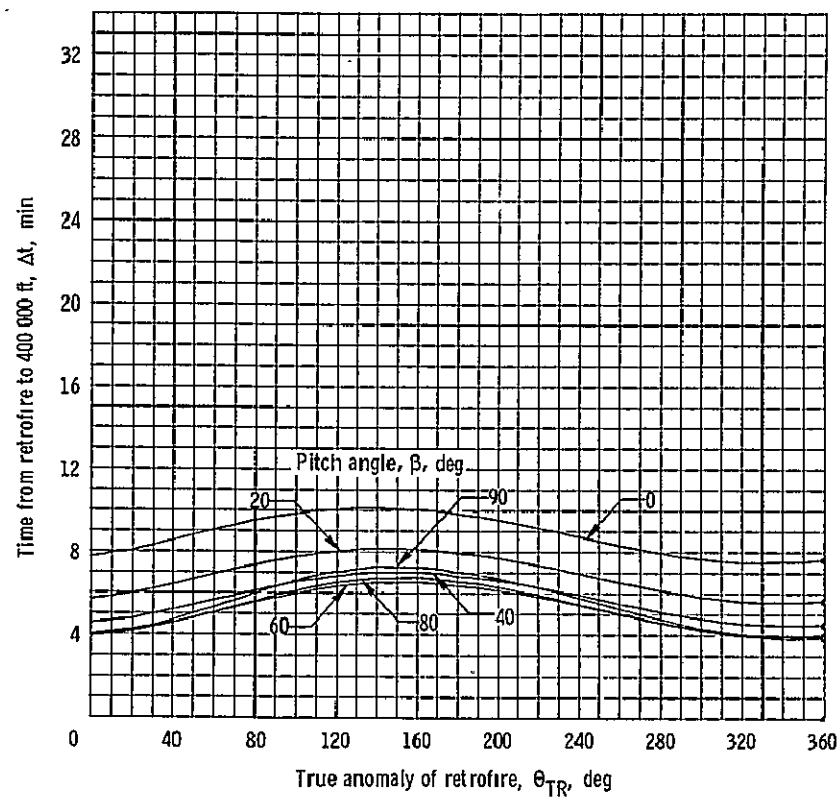
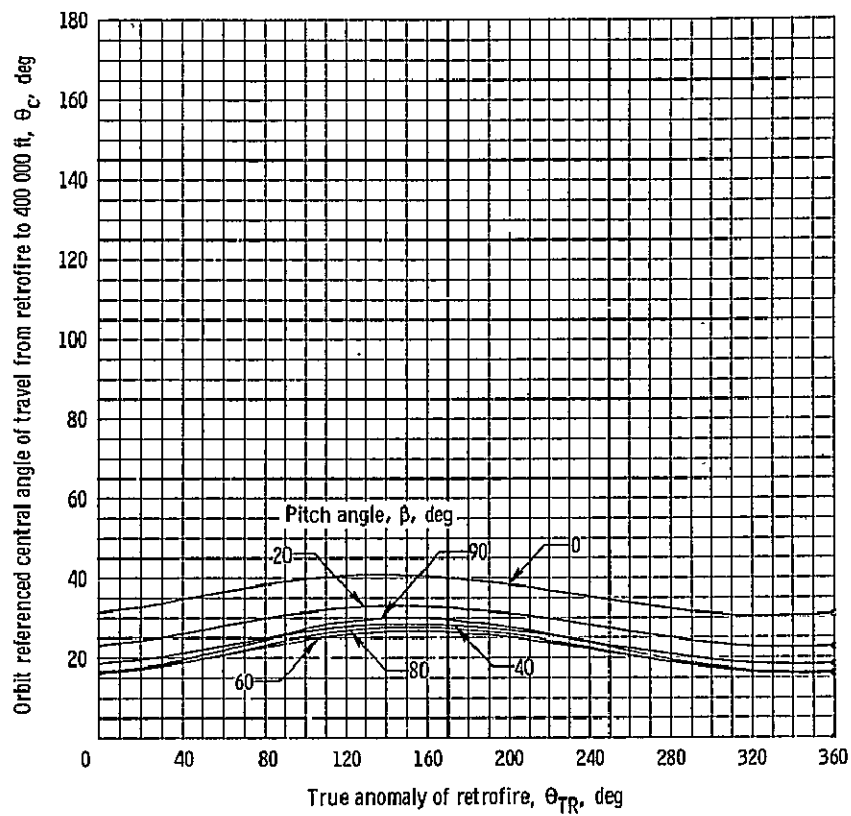
(a) Retrograde $\Delta V = 100$ fps.

Figure 5. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 100$ nautical miles and $h_p = 85$ nautical miles.



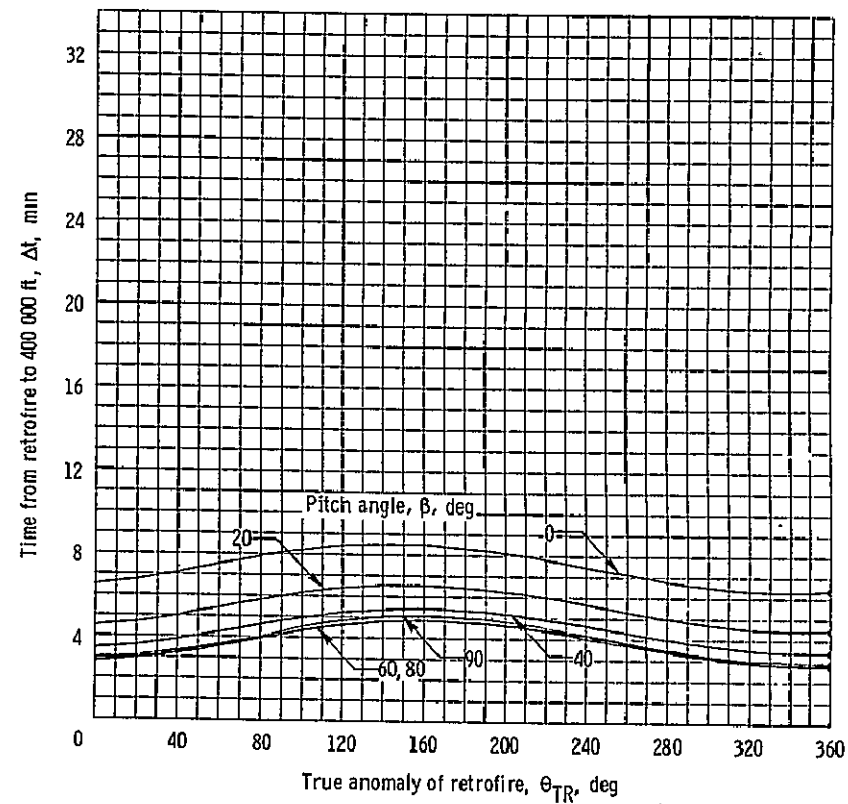
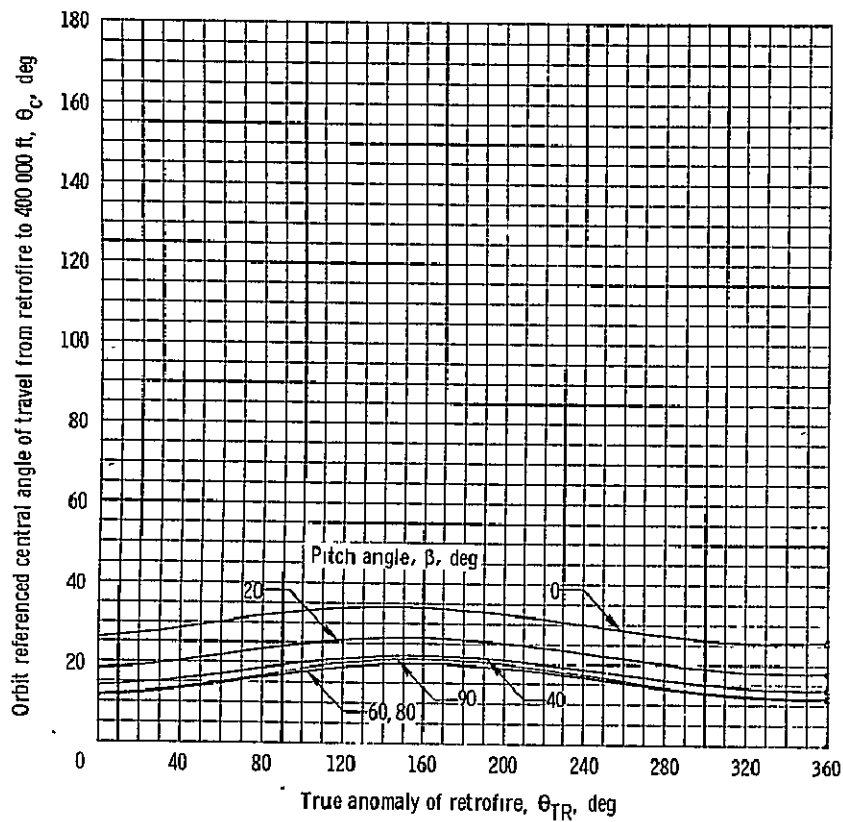
(b) Retrograde $\Delta V = 300$ fps.

Figure 5. - Continued.



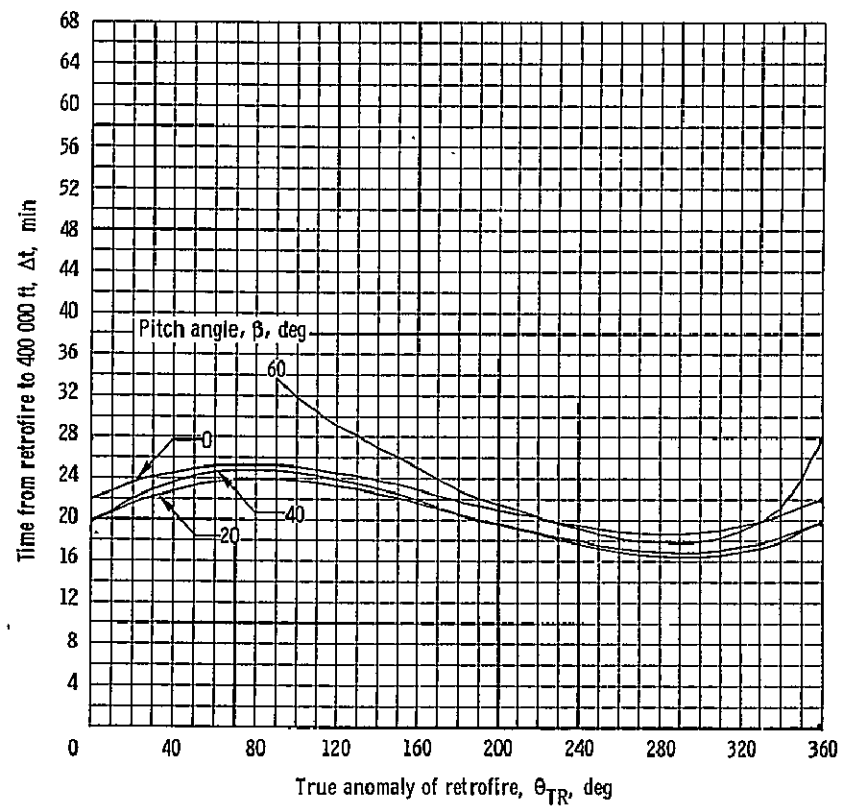
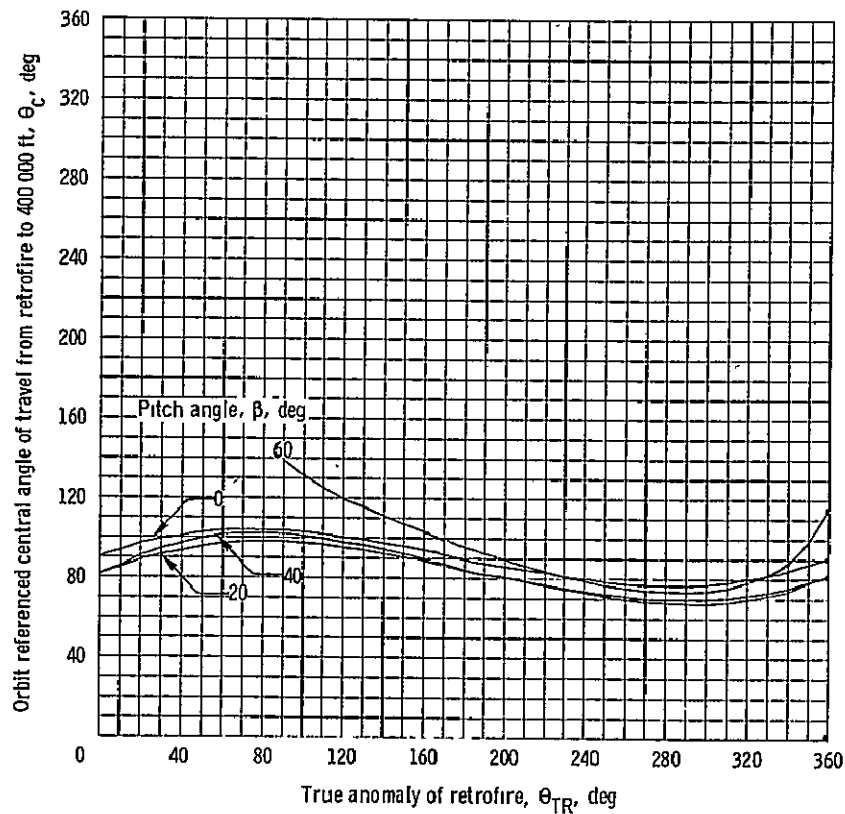
(c) Retrograde $\Delta V = 500$ fps.

Figure 5. - Continued.



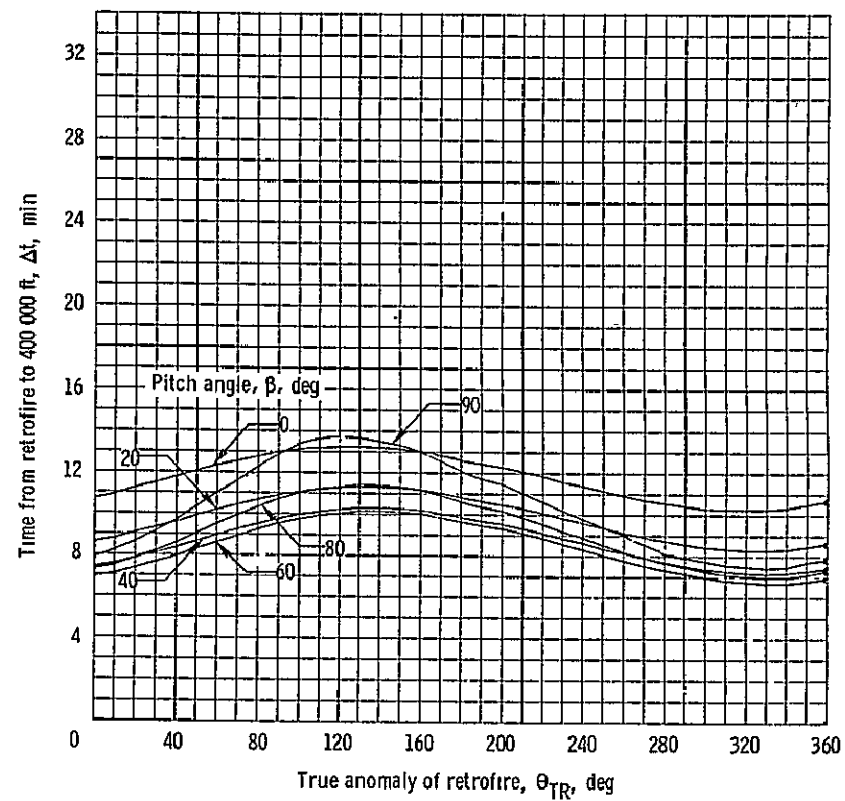
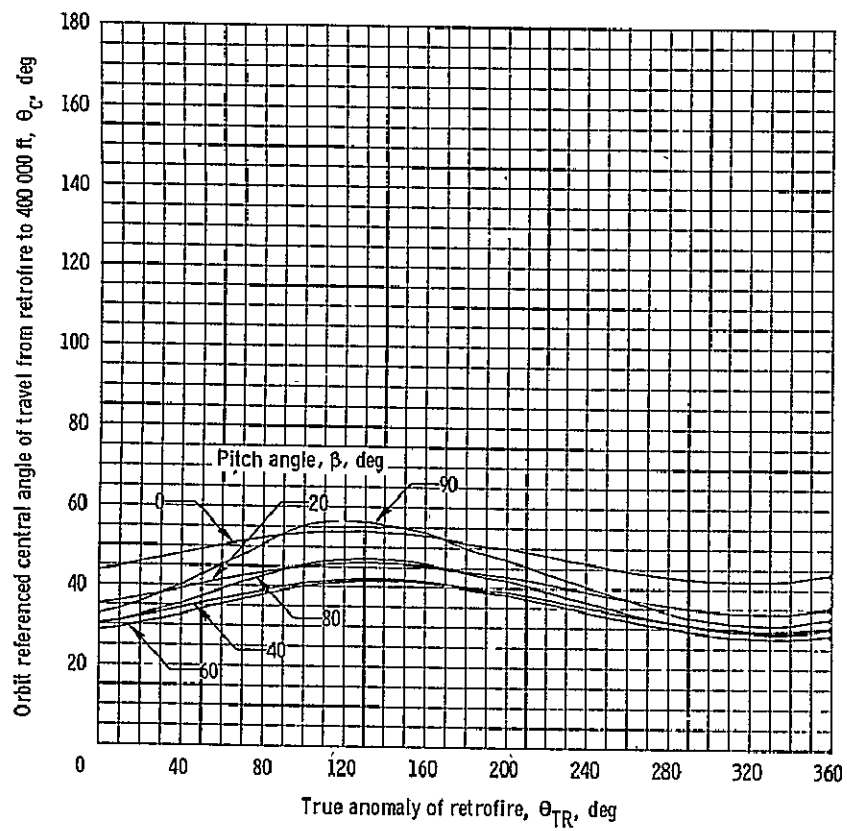
(d) Retrograde $\Delta V = 700$ fps.

Figure 5. - Concluded.



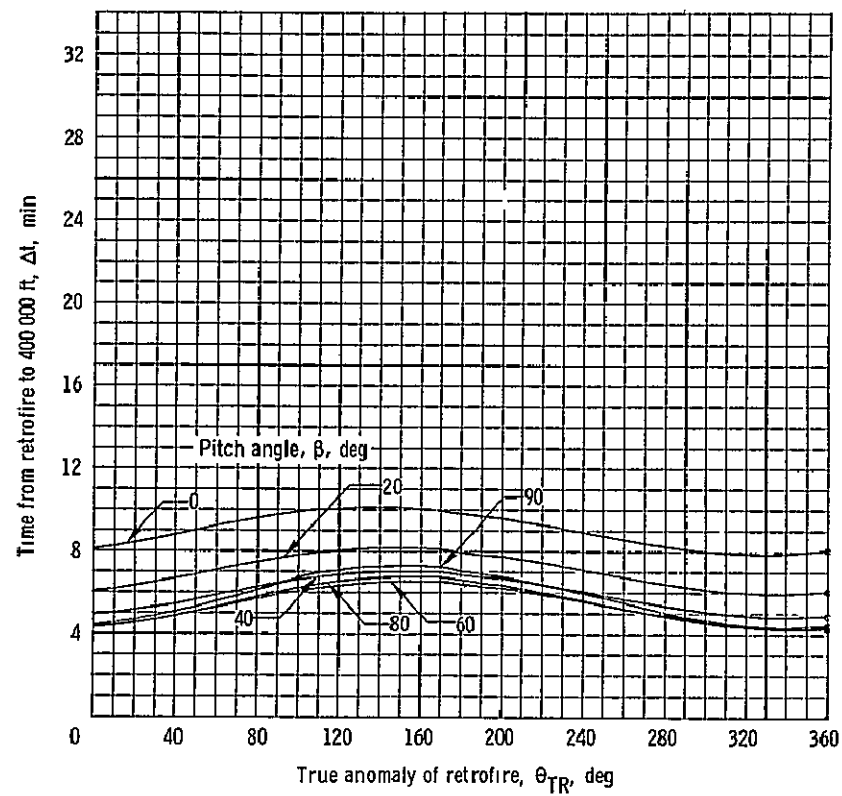
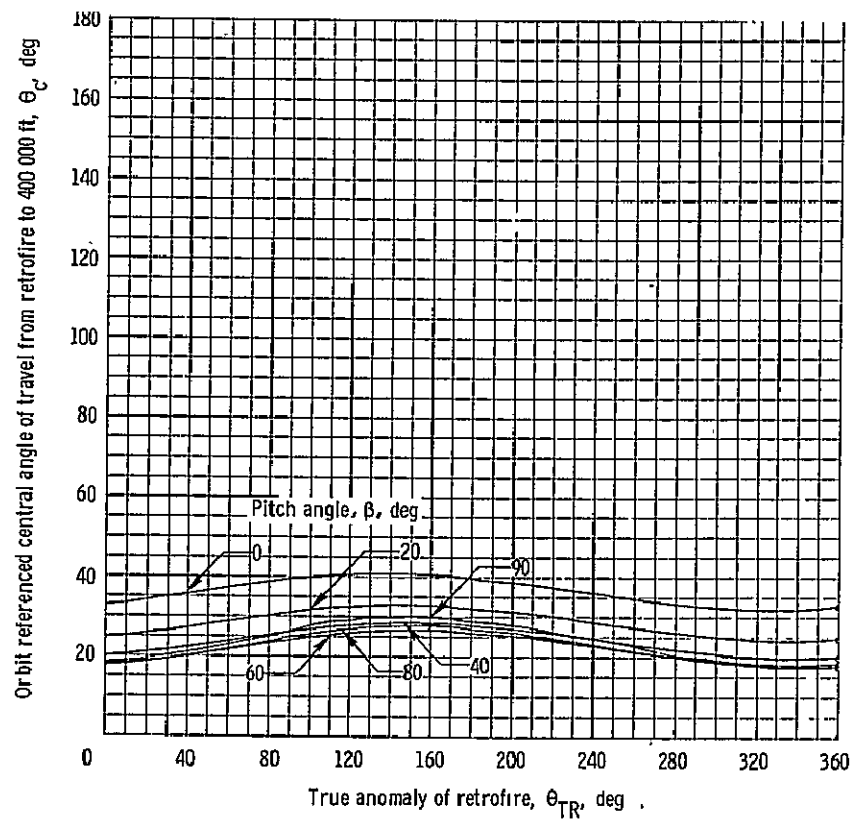
(a) Retrograde $\Delta V = 100$ fps.

Figure 6. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 100$ nautical miles and $h_p = 87$ nautical miles.



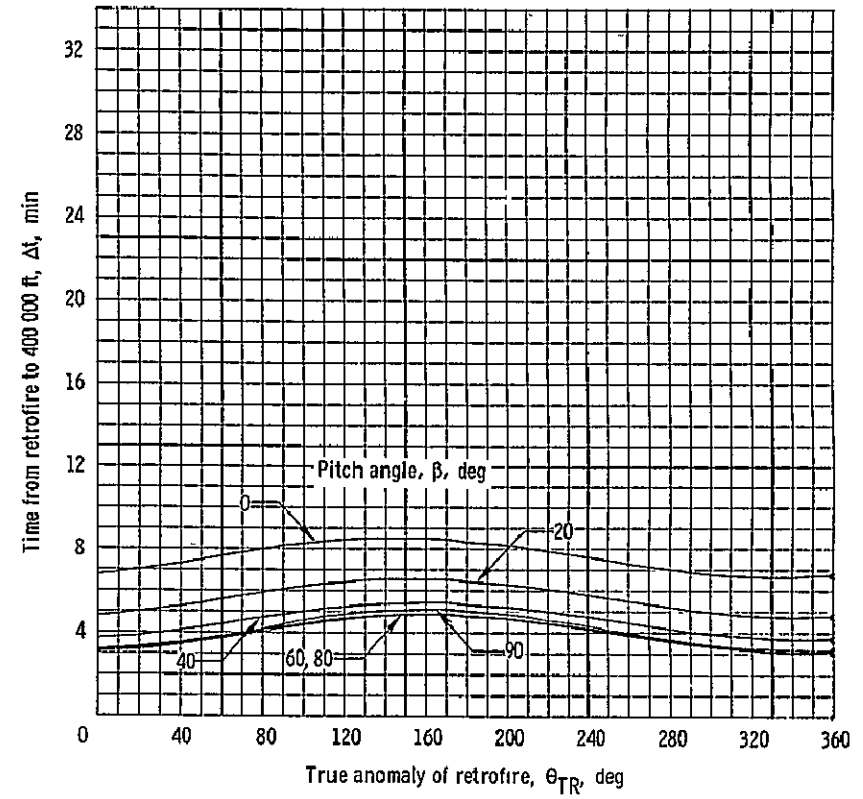
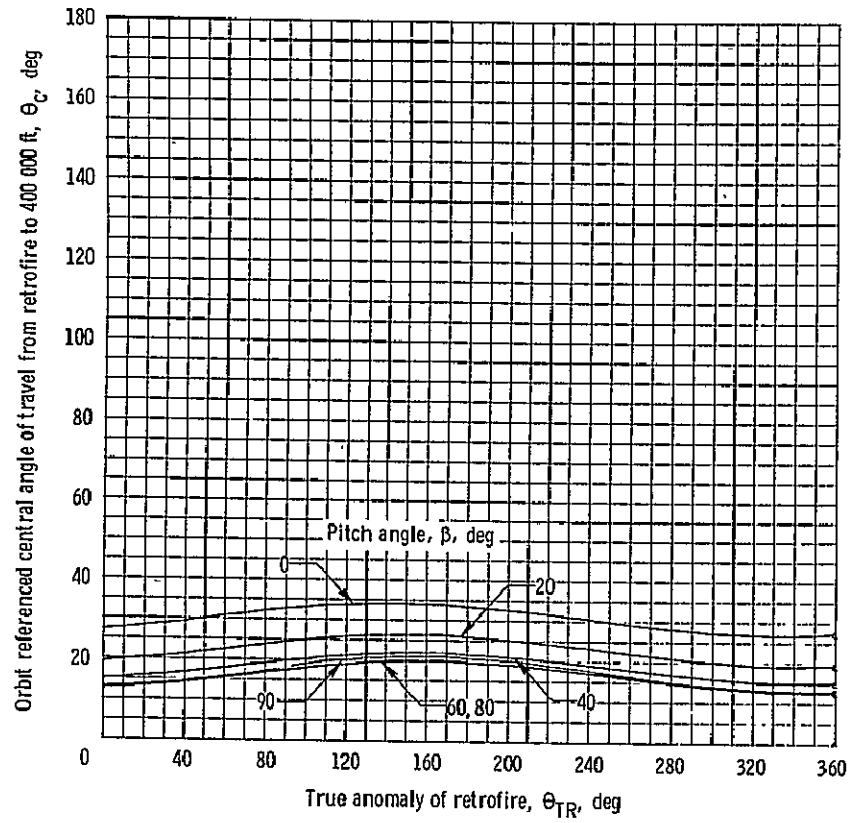
(b) Retrograde $\Delta V = 300$ fps.

Figure 6. - Continued.



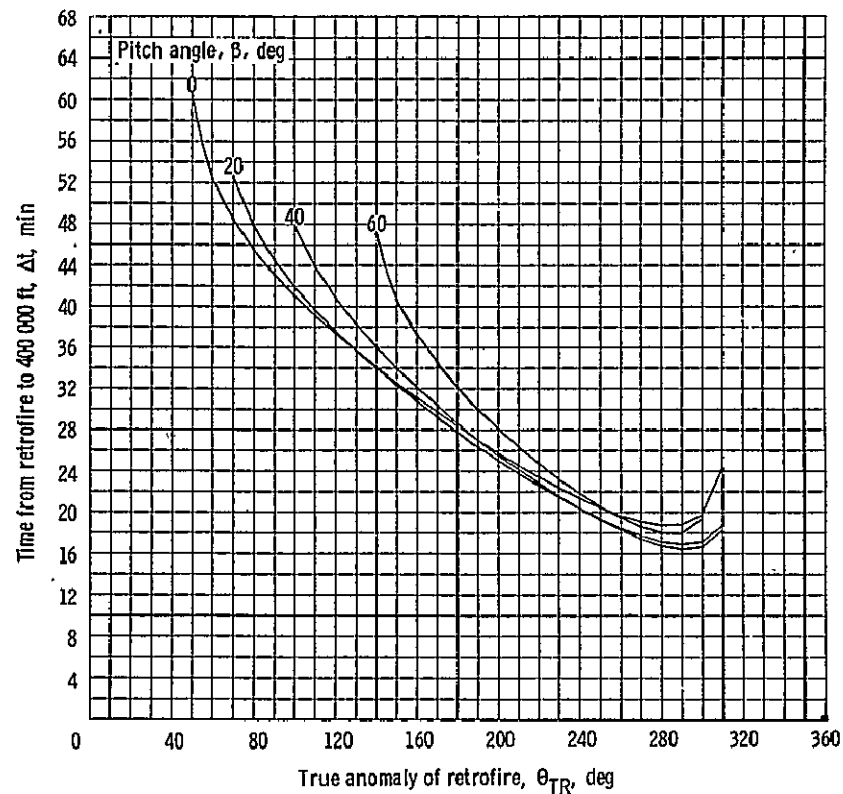
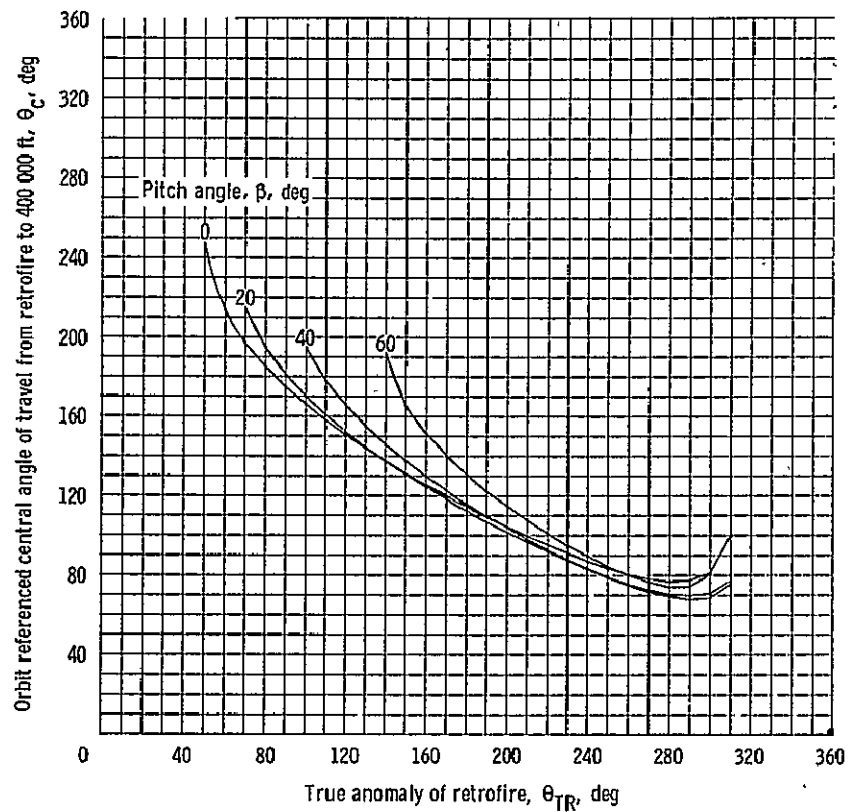
(c) Retrograde $\Delta V = 500$ fps.

Figure 6. - Continued.



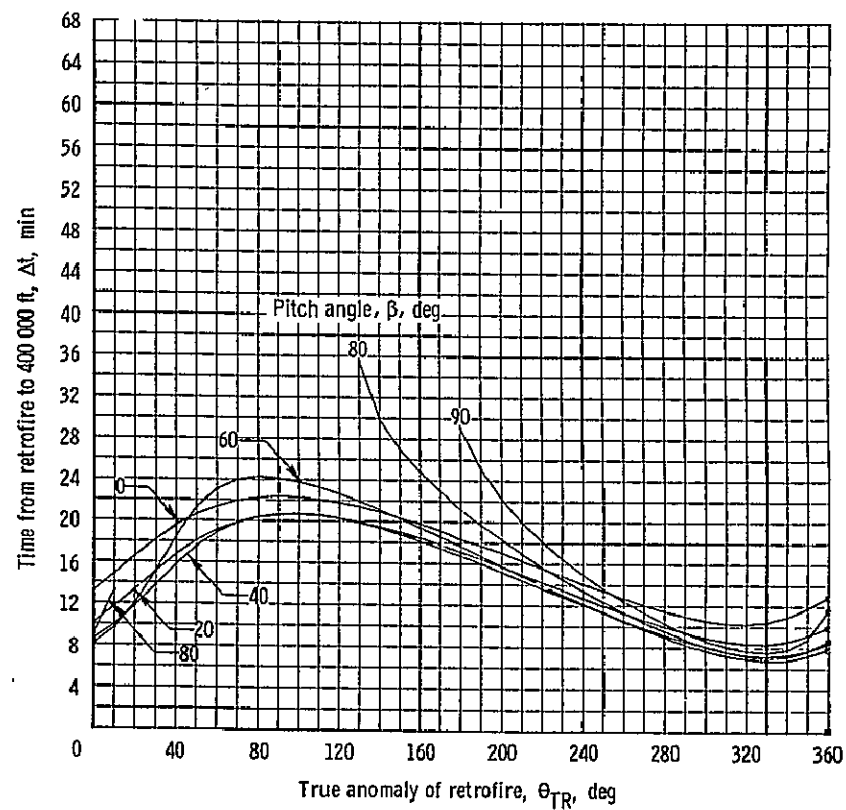
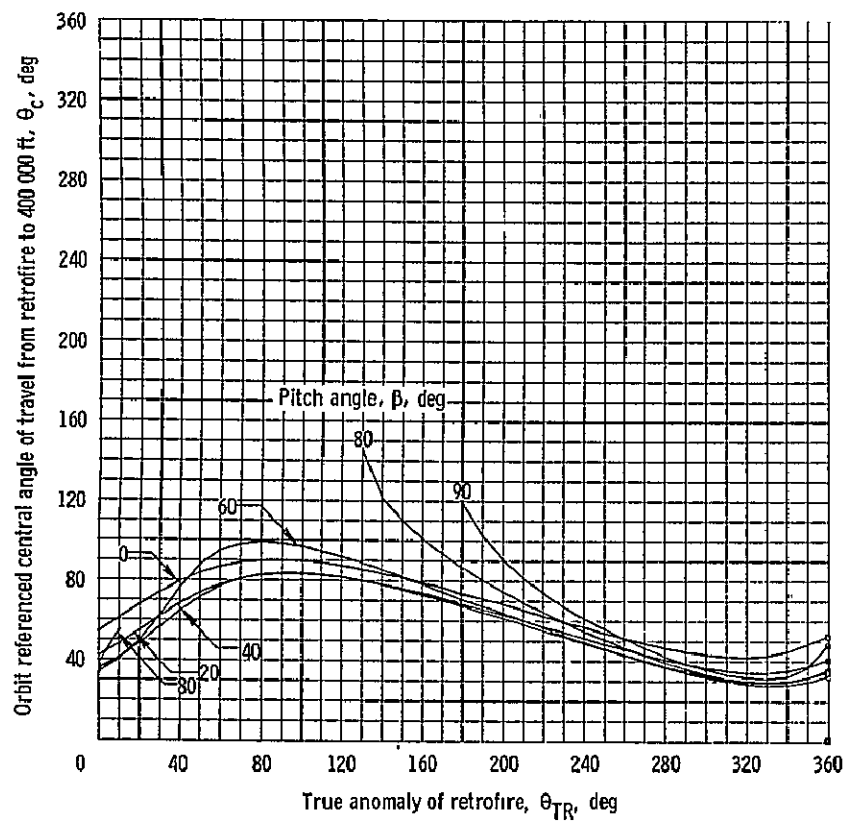
(d) Retrograde $\Delta V = 700$ fps.

Figure 6. - Concluded.



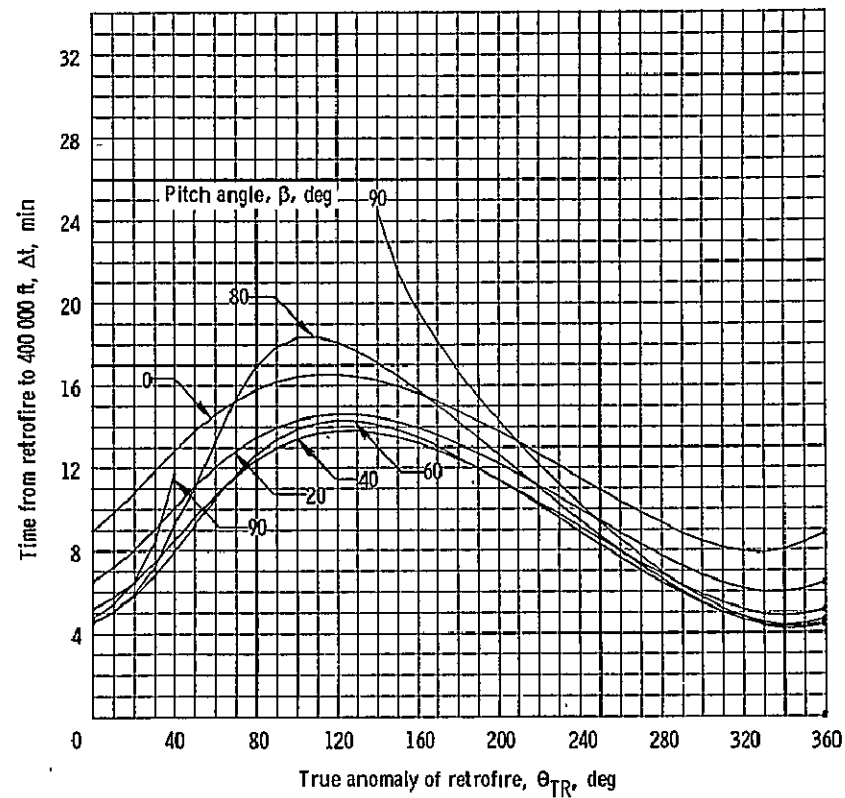
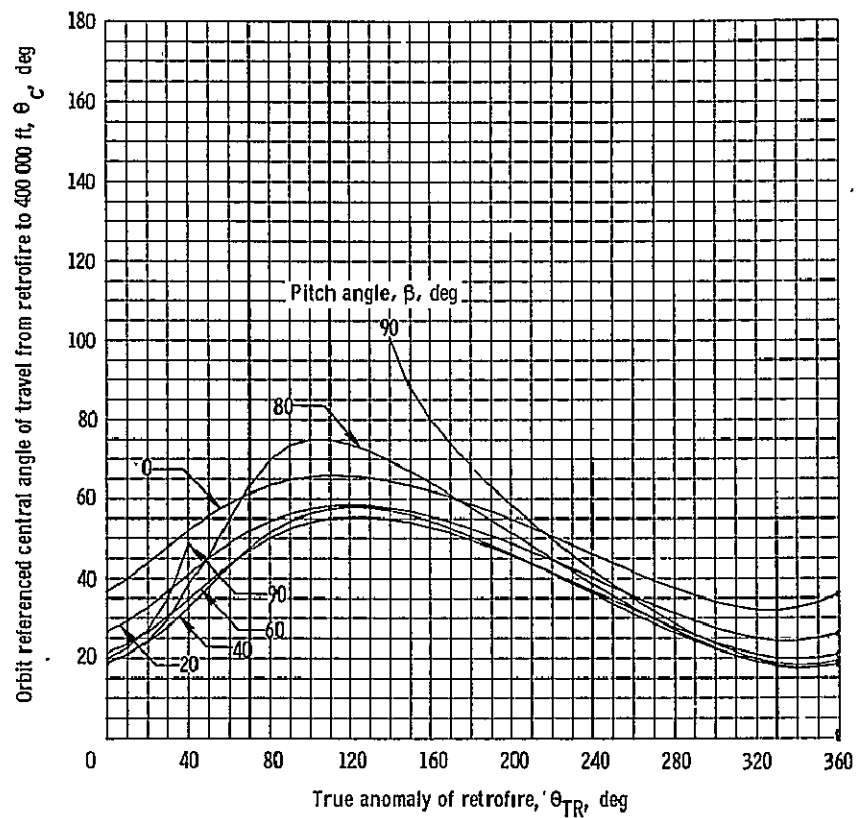
(a) Retrograde $\Delta V = 100$ fps.

Figure 7. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 150$ nautical miles and $h_p = 87$ nautical miles.



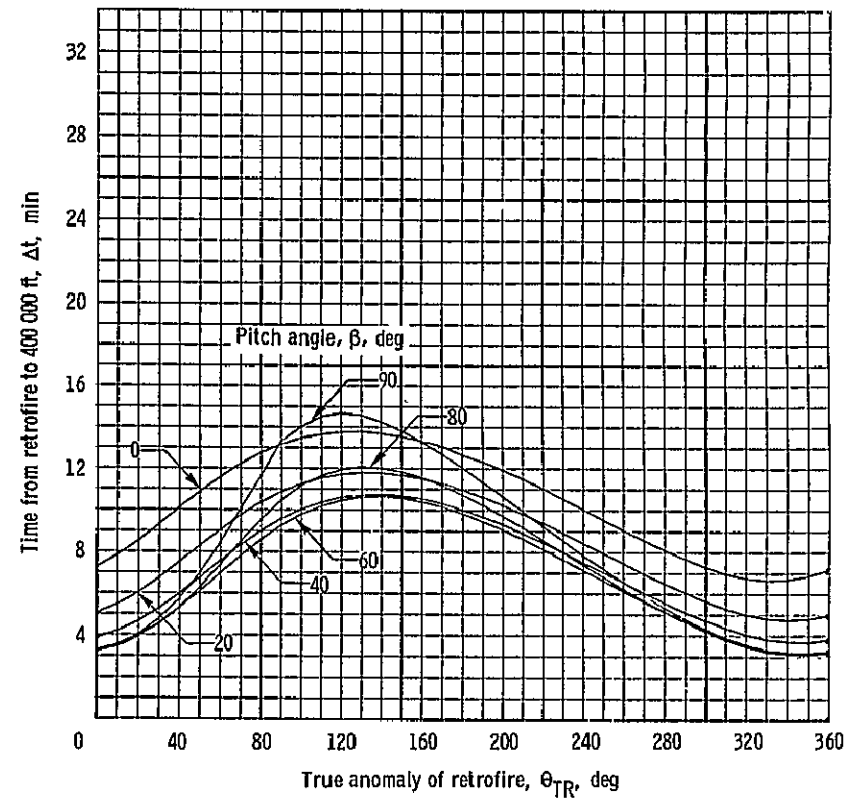
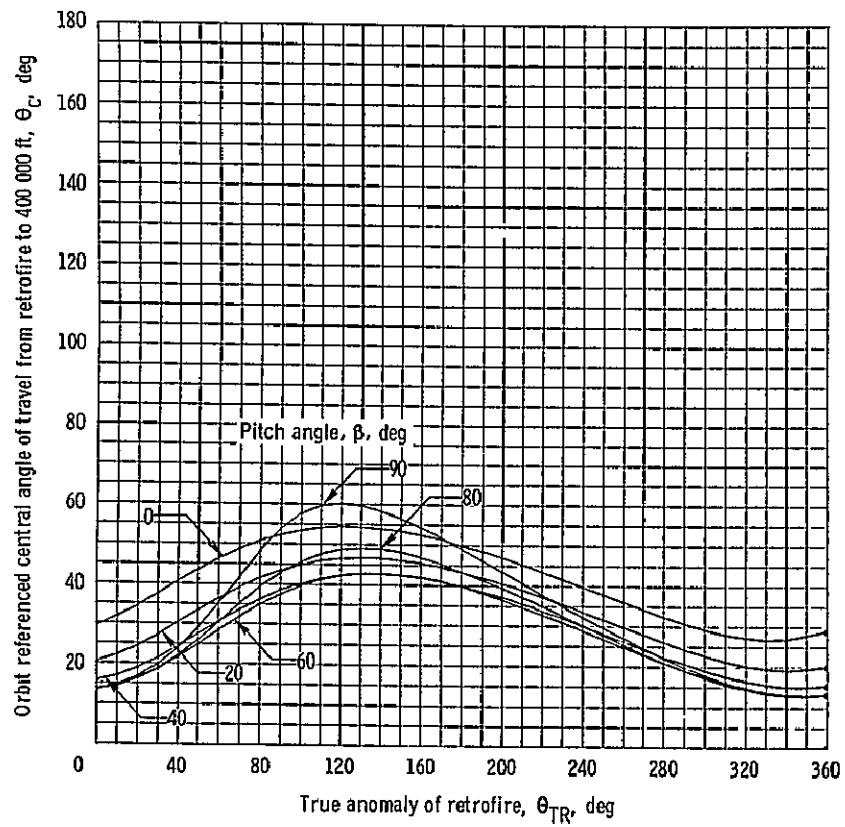
(b) Retrograde $\Delta V = 300$ fps.

Figure 7. - Continued.



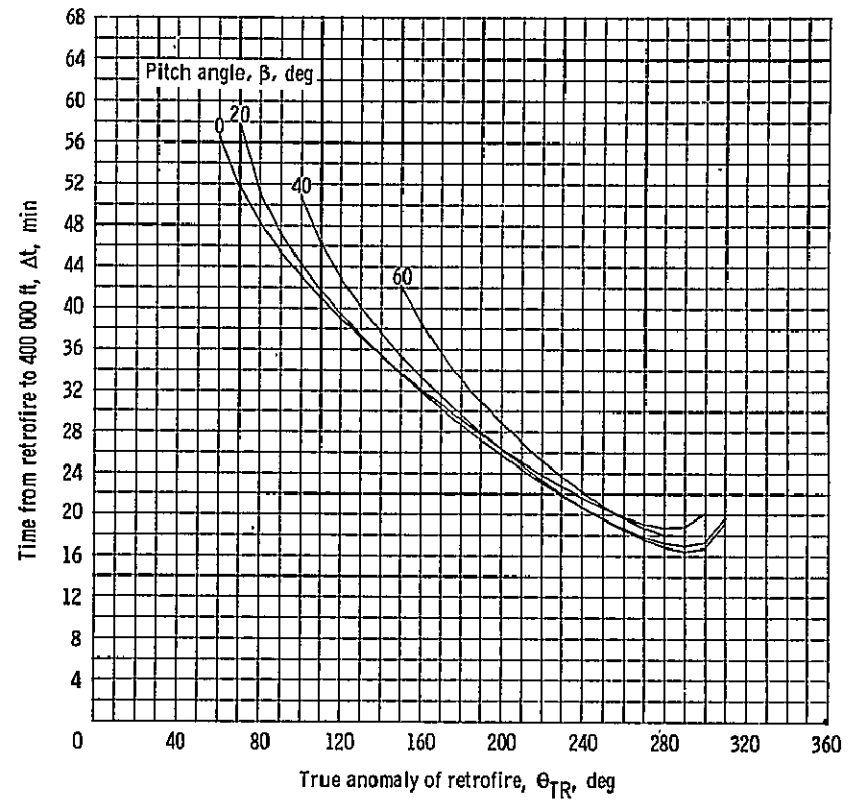
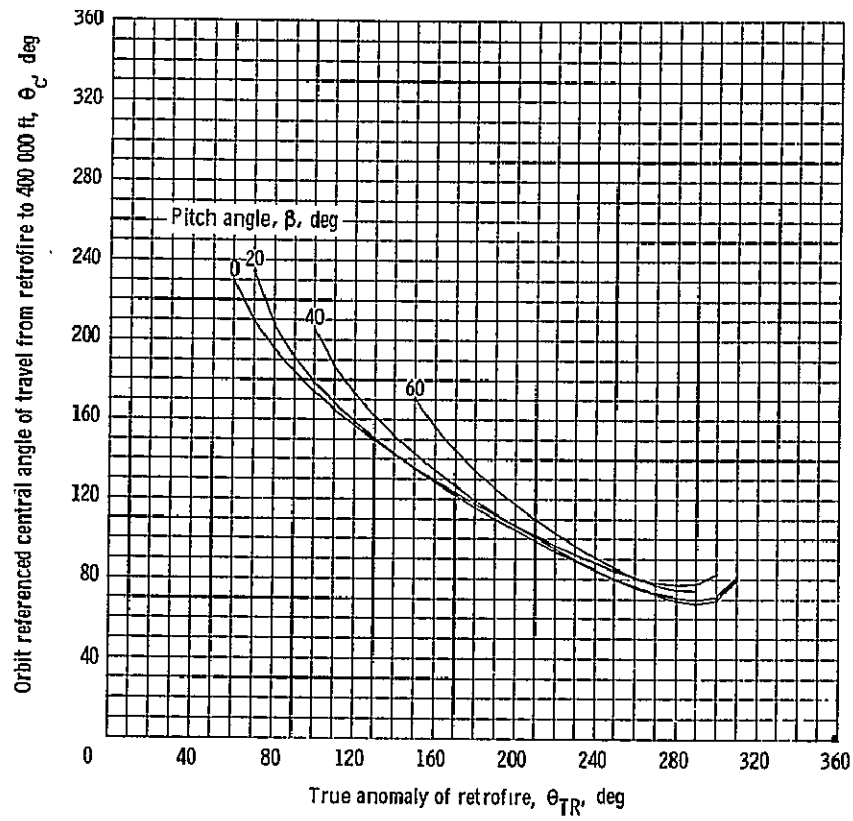
(c) Retrograde $\Delta V = 500$ fps.

Figure 7. - Continued.



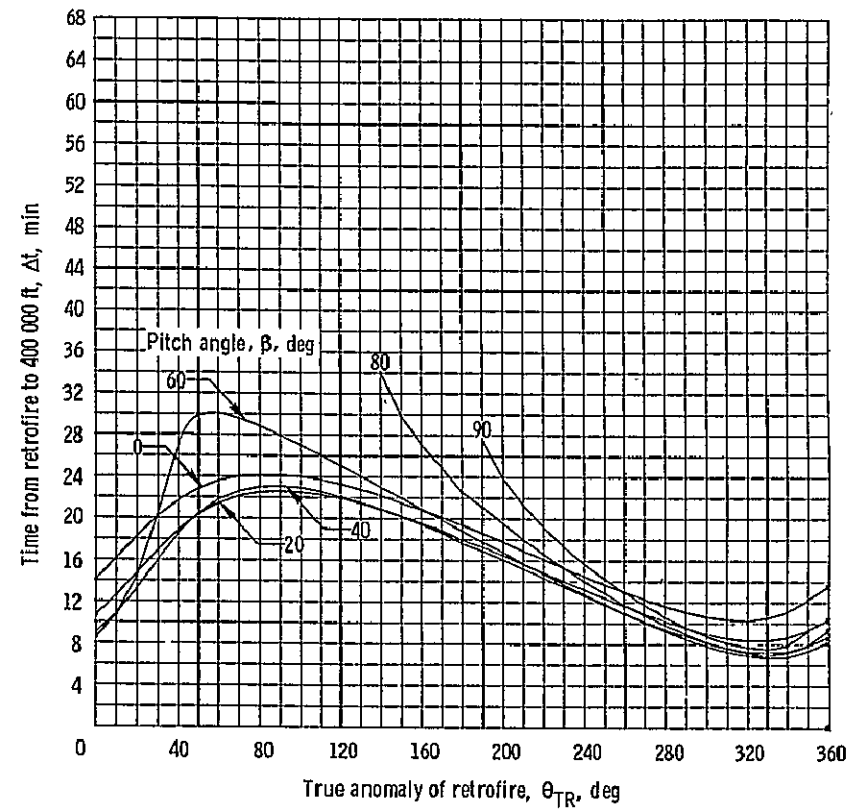
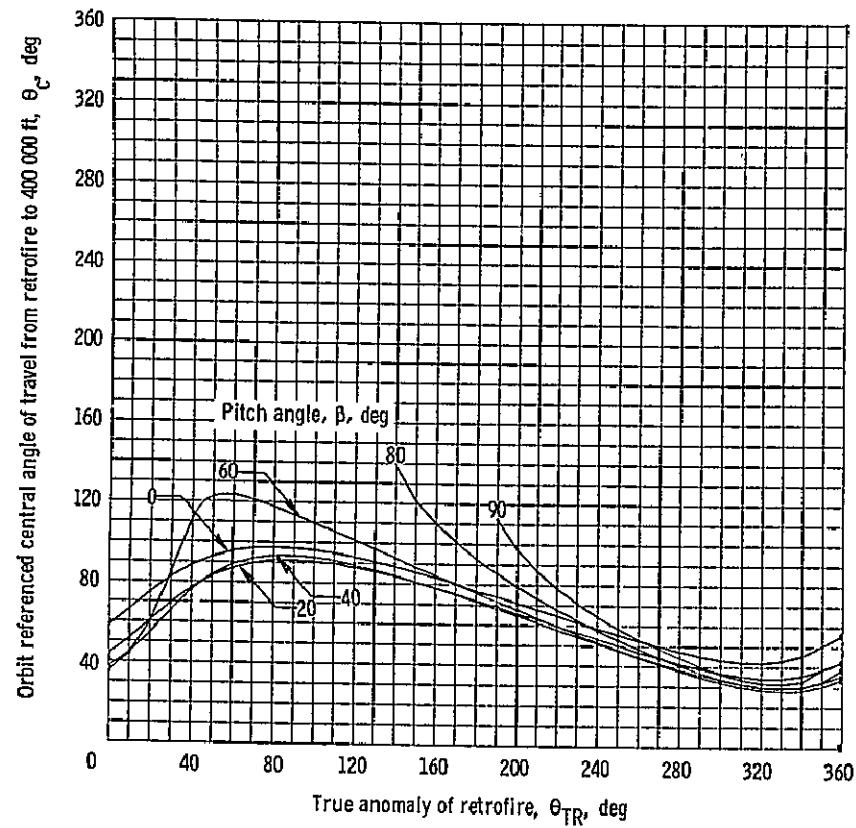
(d) Retrograde $\Delta V = 700$ fps.

Figure 7. - Concluded.



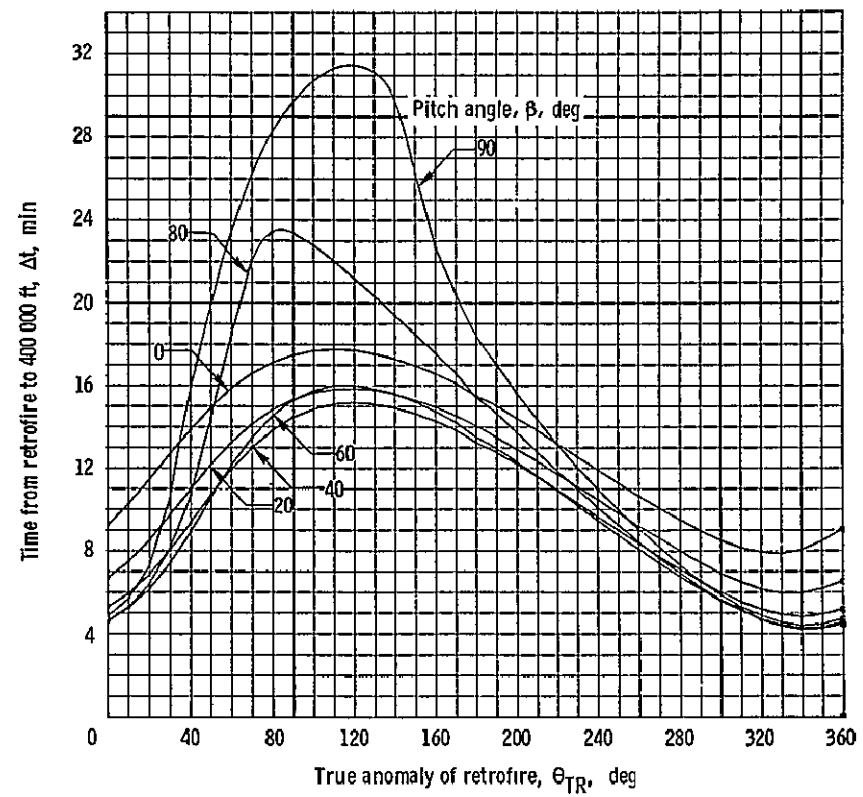
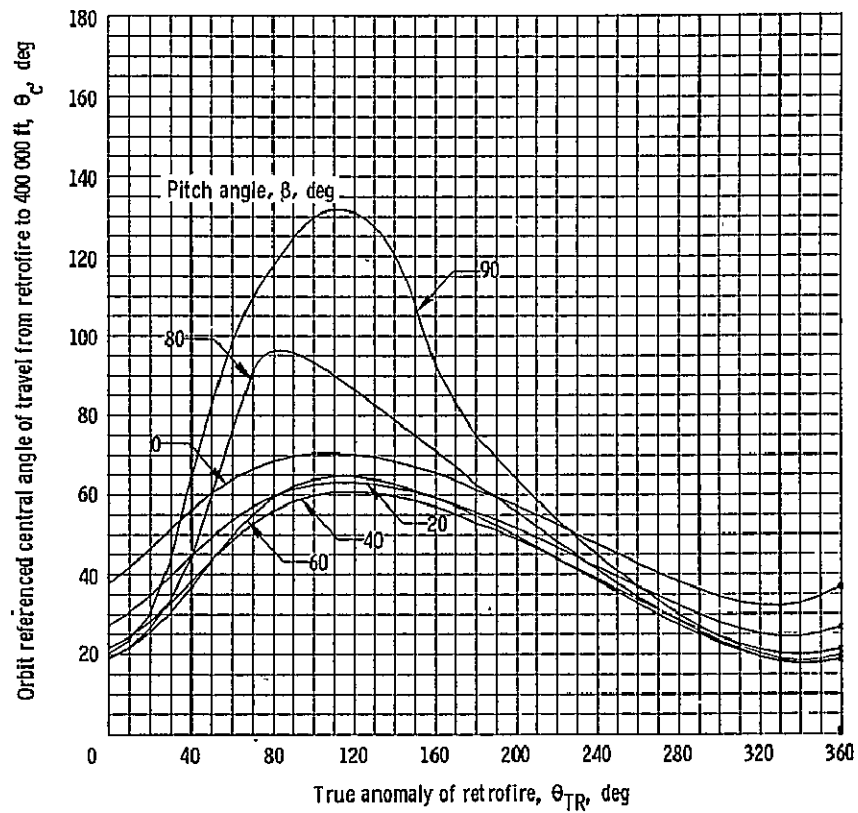
(a) Retrograde $\Delta V = 100$ fps.

Figure 8. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 161$ nautical miles and $h_p = 87$ nautical miles.



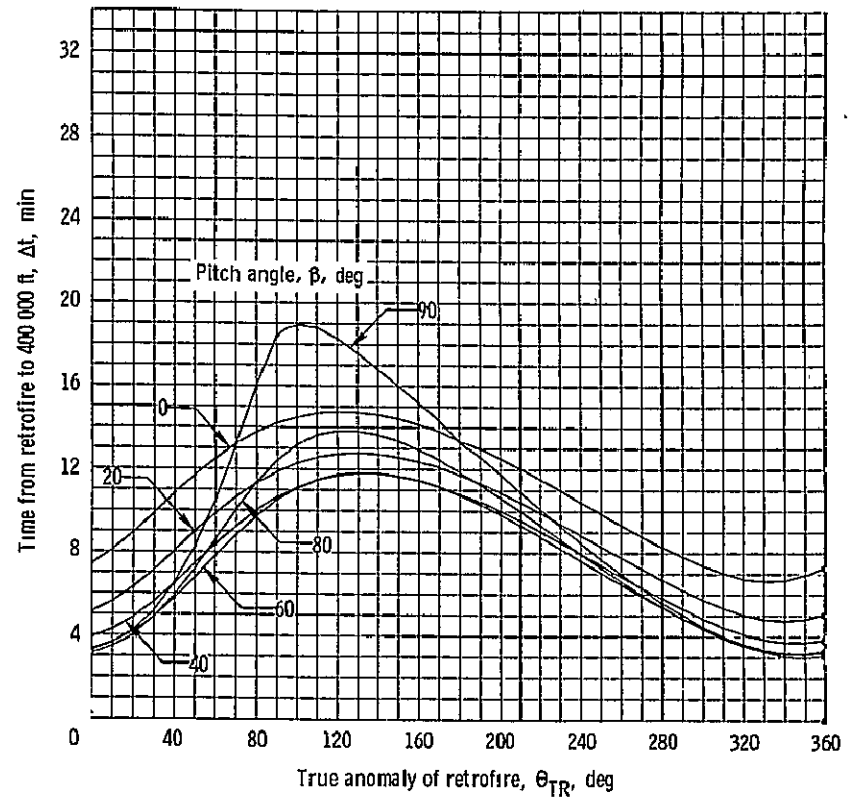
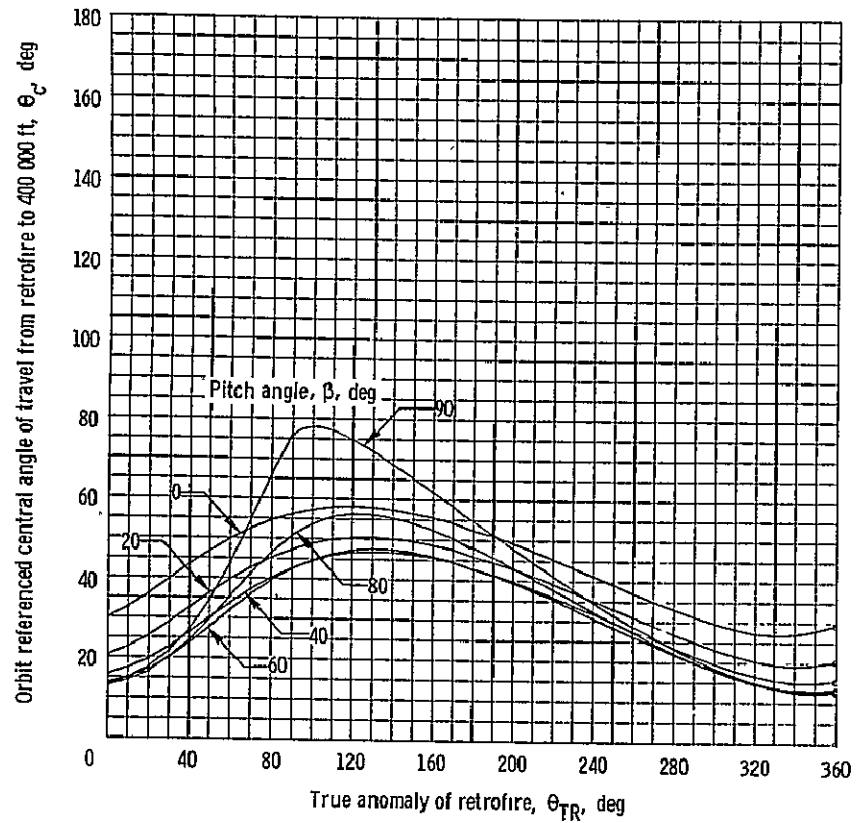
(b) Retrograde $\Delta V = 300$ fps.

Figure 8. - Continued.



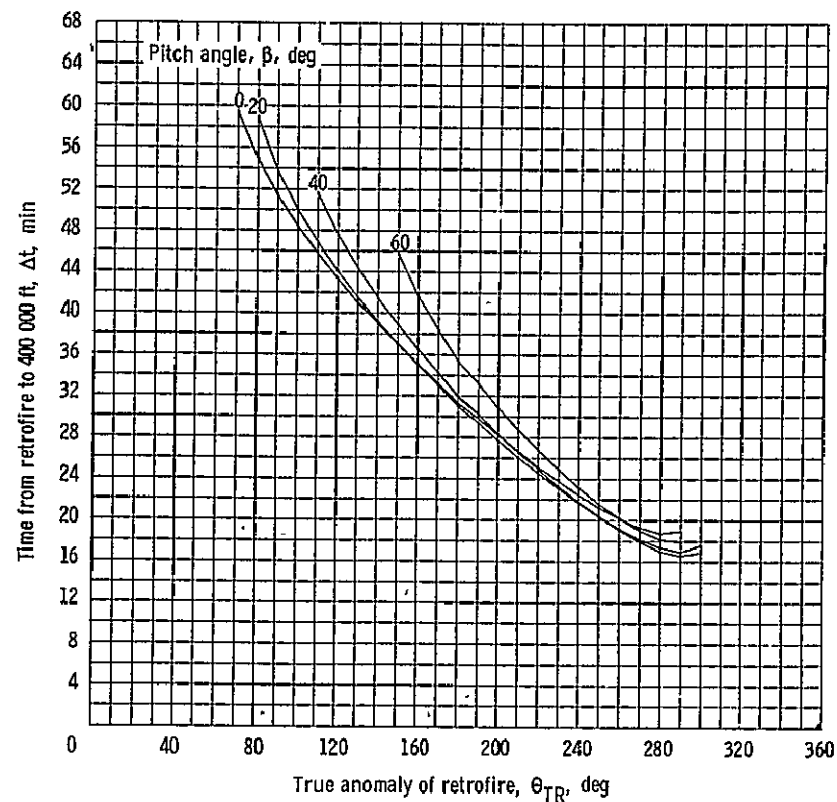
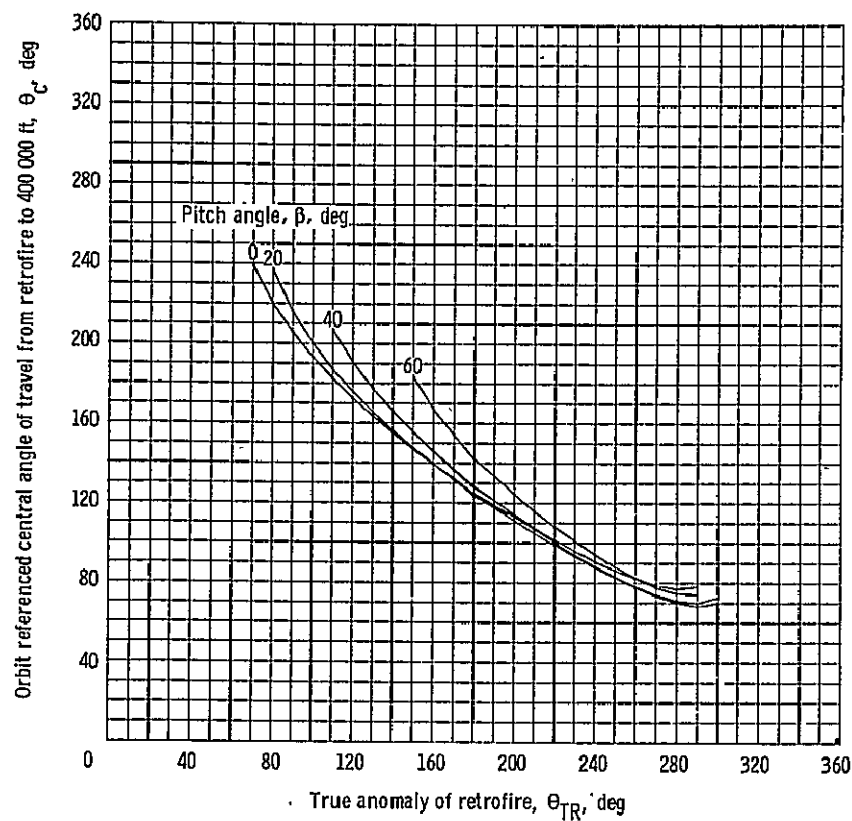
(c) Retrograde $\Delta V = 500$ fps.

Figure 8. - Continued.



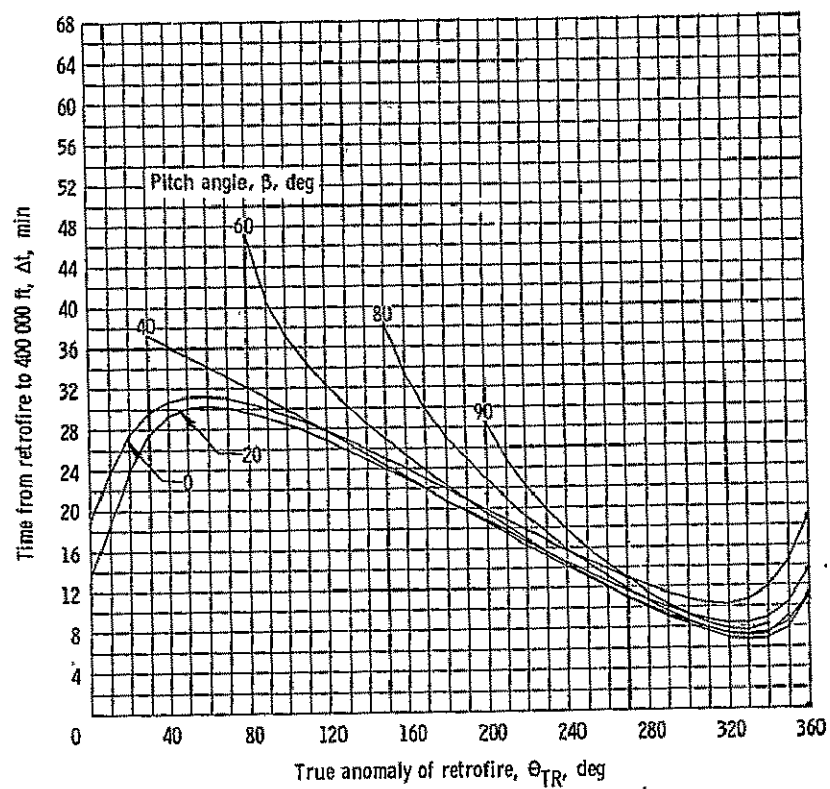
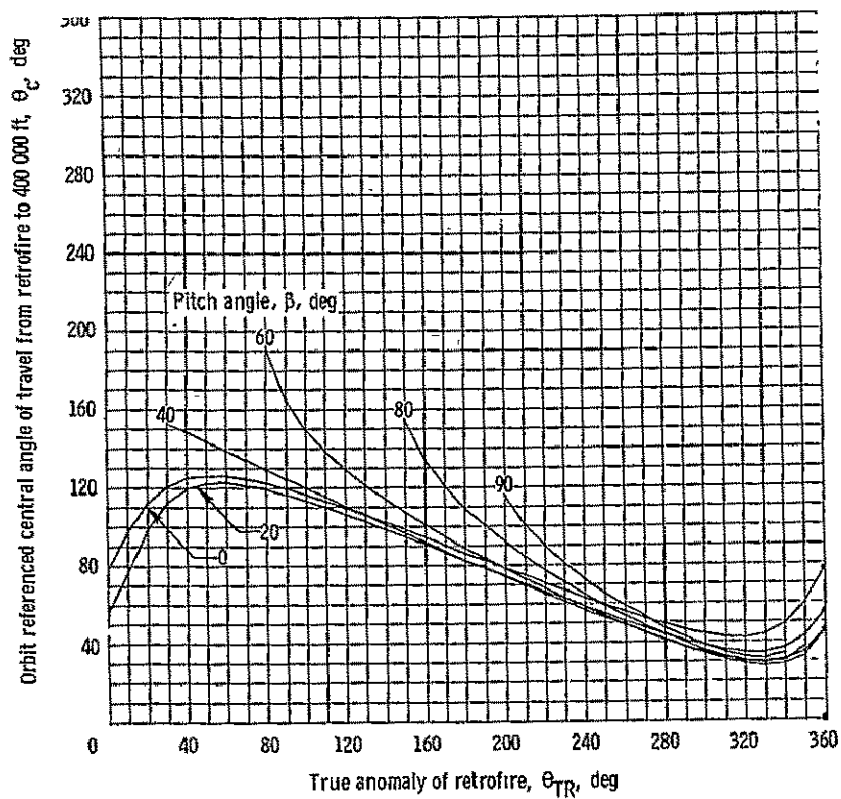
(d) Retrograde $\Delta V = 700$ fps.

Figure 8. - Concluded.



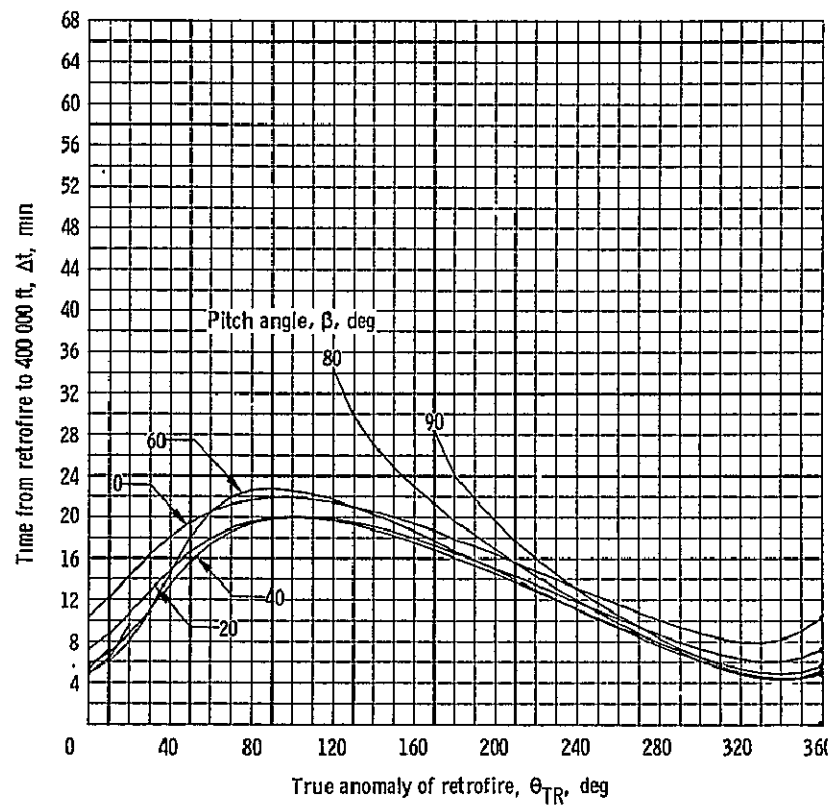
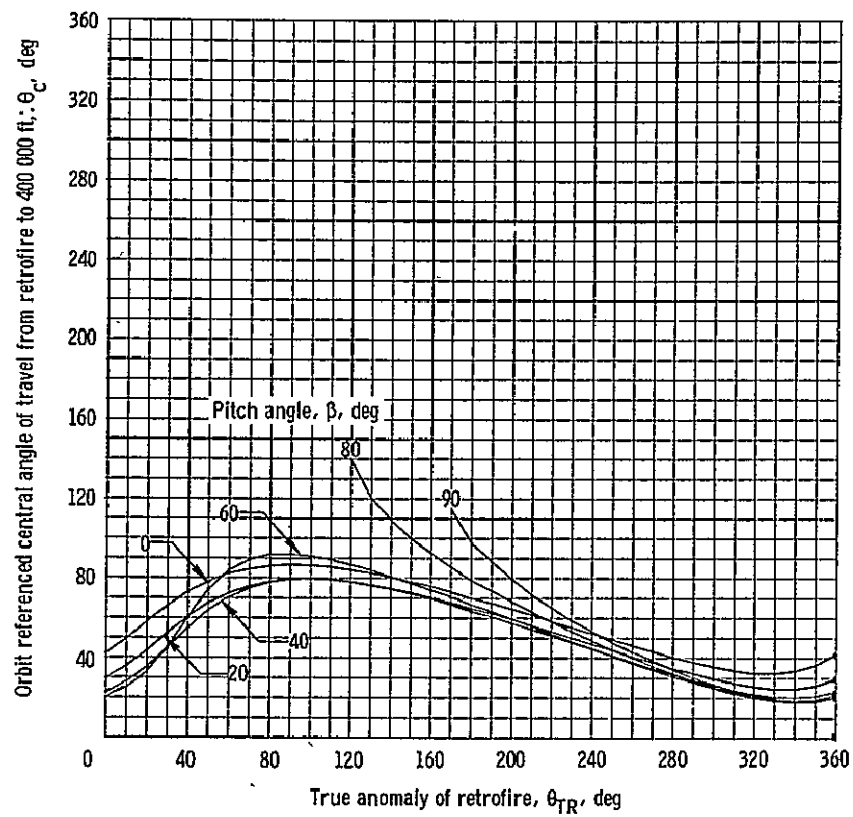
(a) Retrograde $\Delta V = 100$ fps.

Figure 9. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 200$ nautical miles and $h_p = 87$ nautical miles.



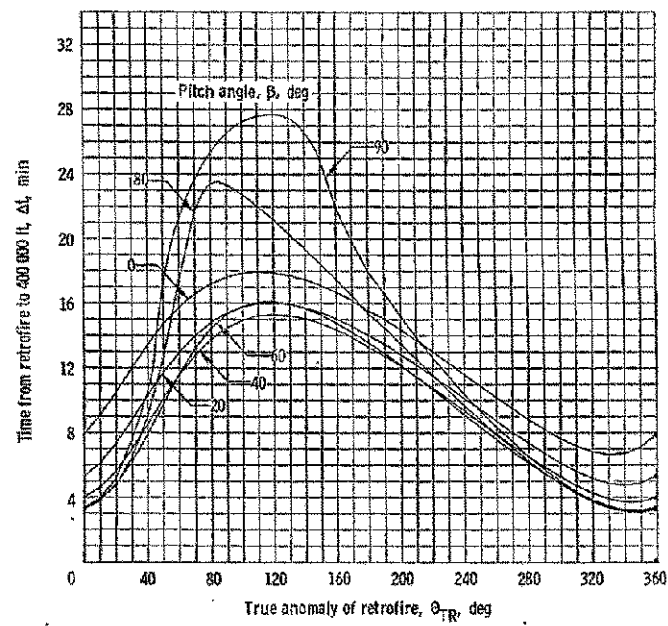
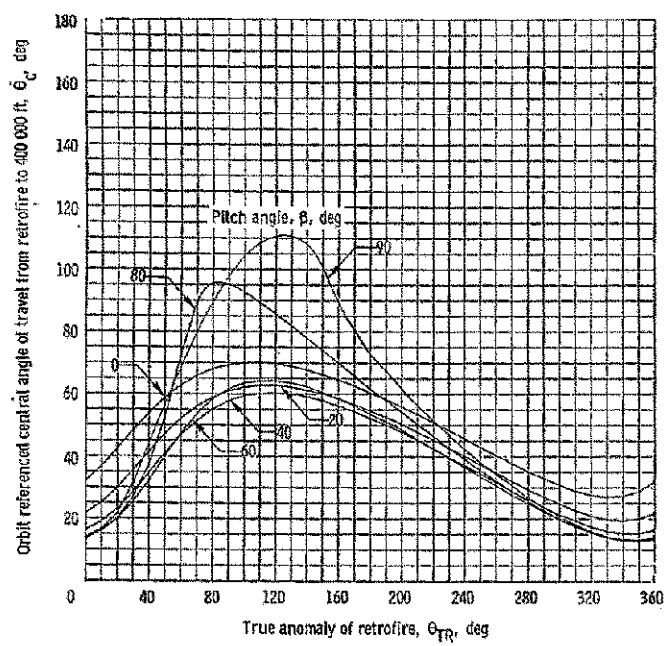
(b) Retrograde $\Delta V = 300$ fps.

Figure 9. - Continued.



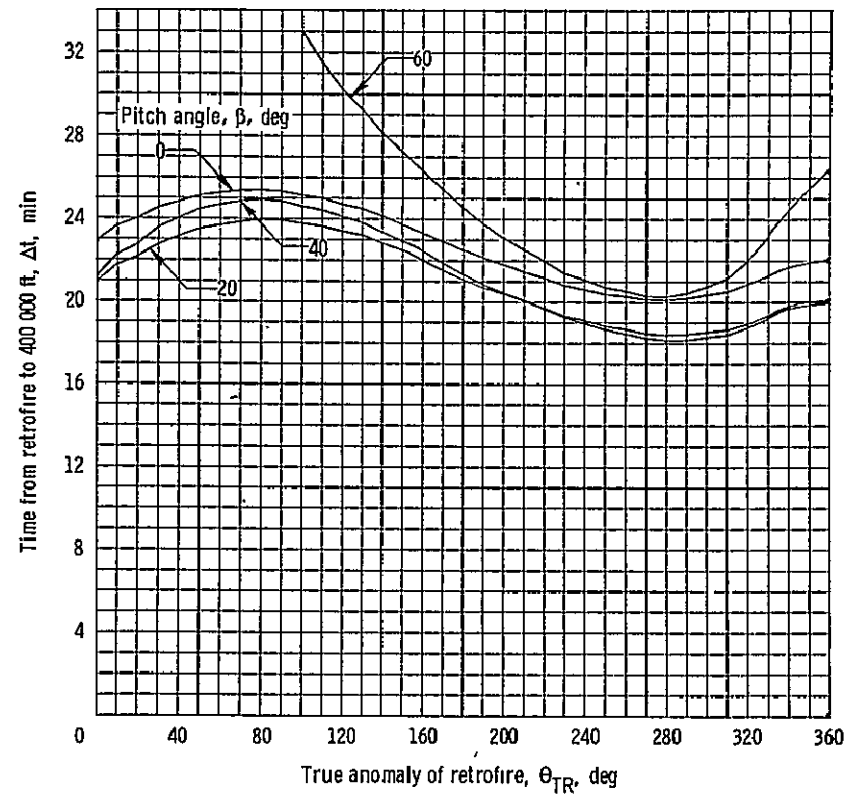
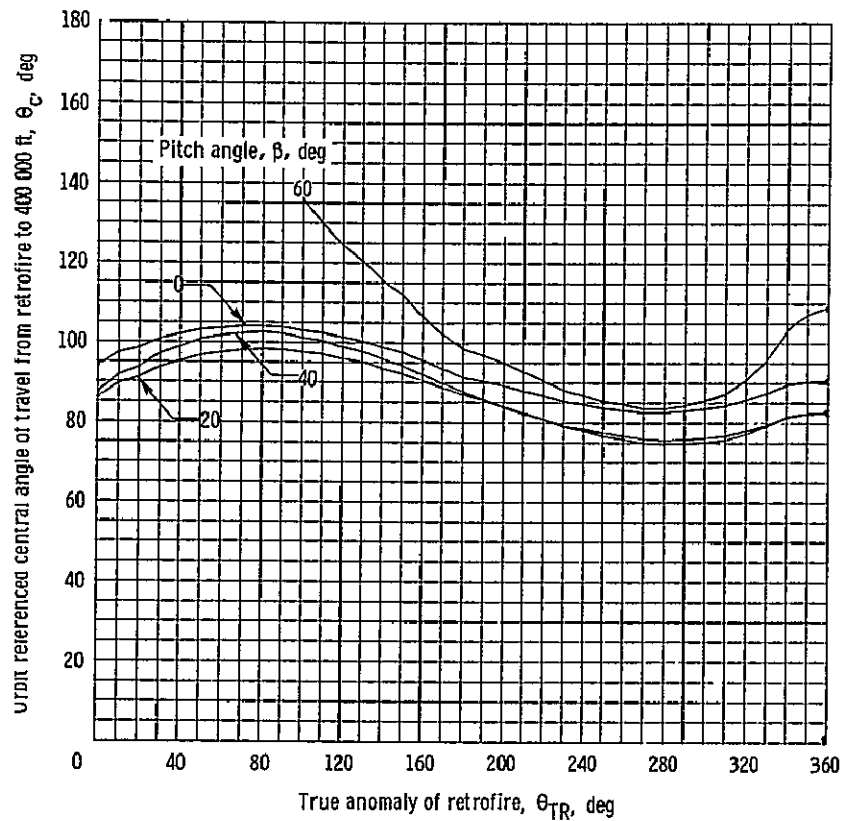
(c) Retrograde $\Delta V = 500$ fps.

Figure 9. - Continued.



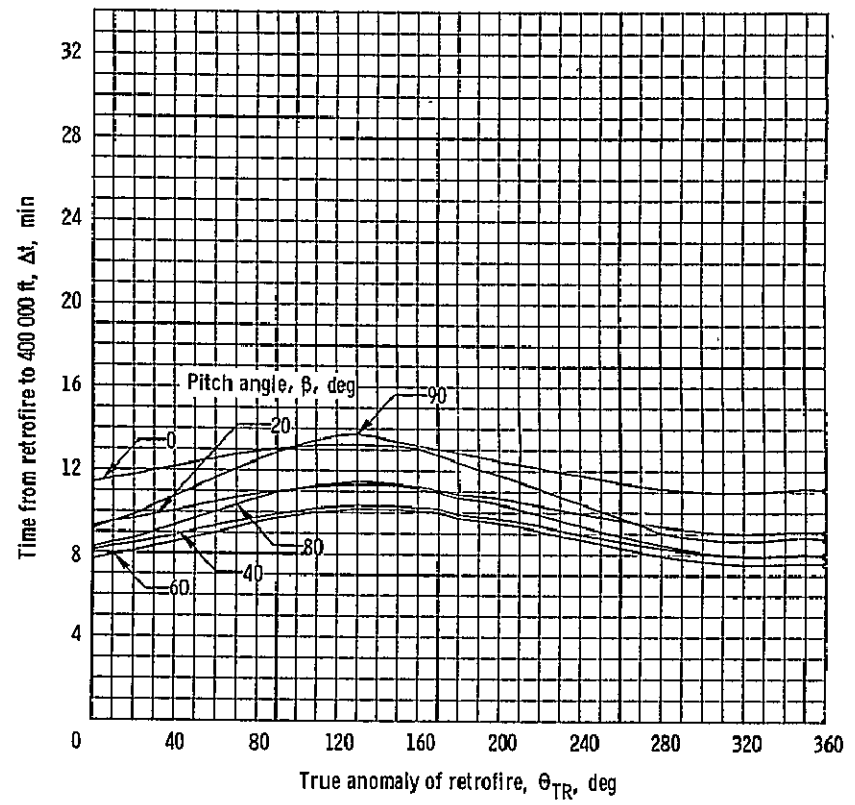
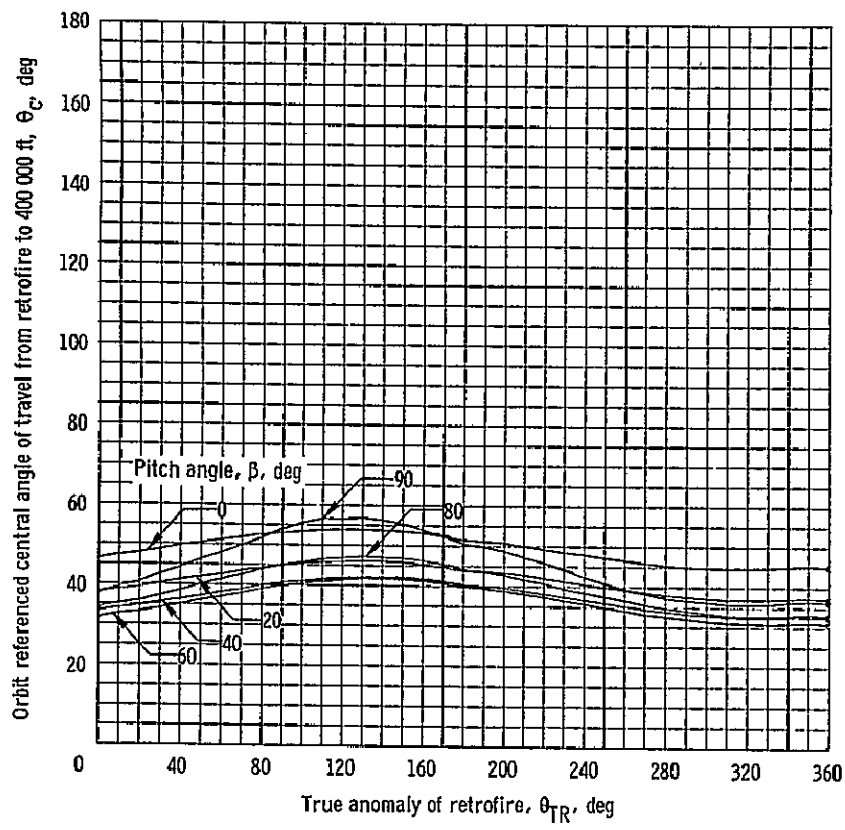
(d) Retrograde $\Delta V = 700$ fps.

Figure 9. - Concluded.



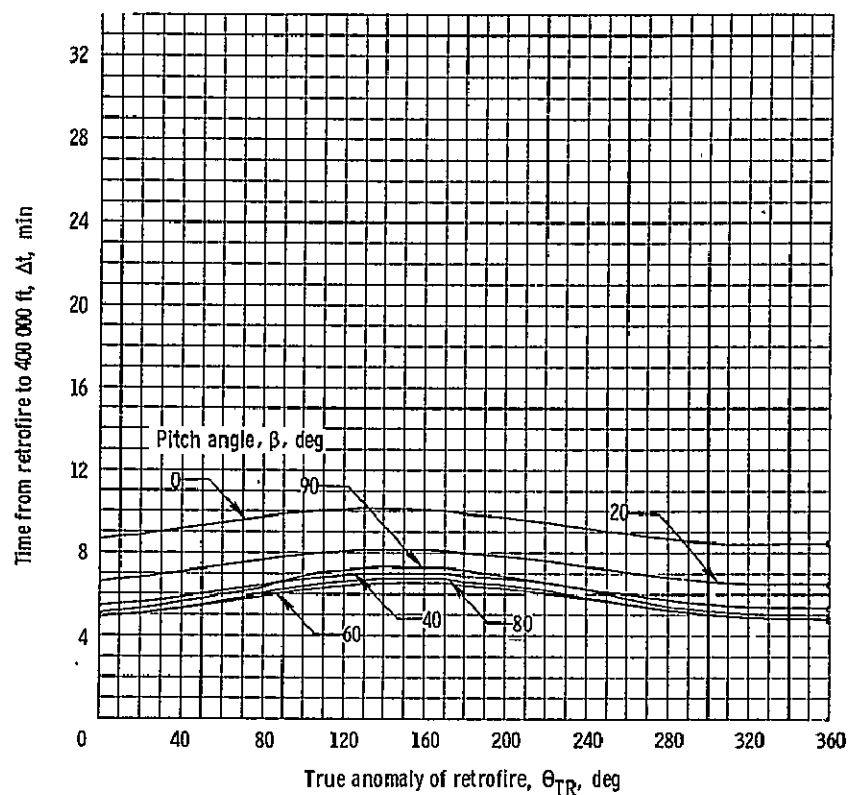
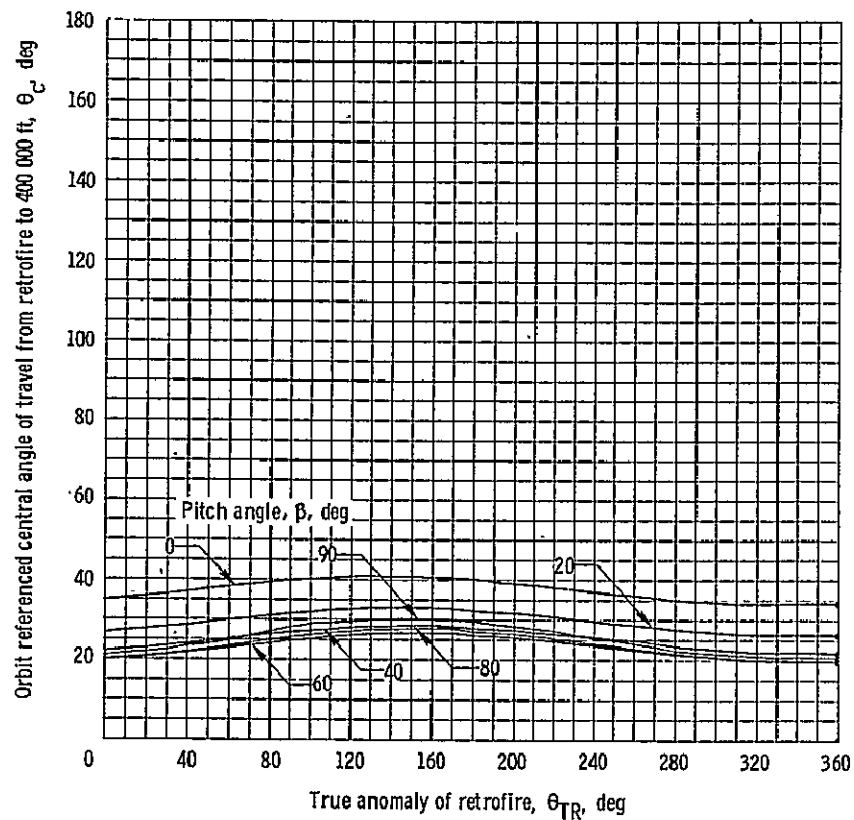
(a Retrograde $\Delta V = 100$ fps.

Figure 10. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 100$ nautical miles and $h_p = 90$ nautical miles.



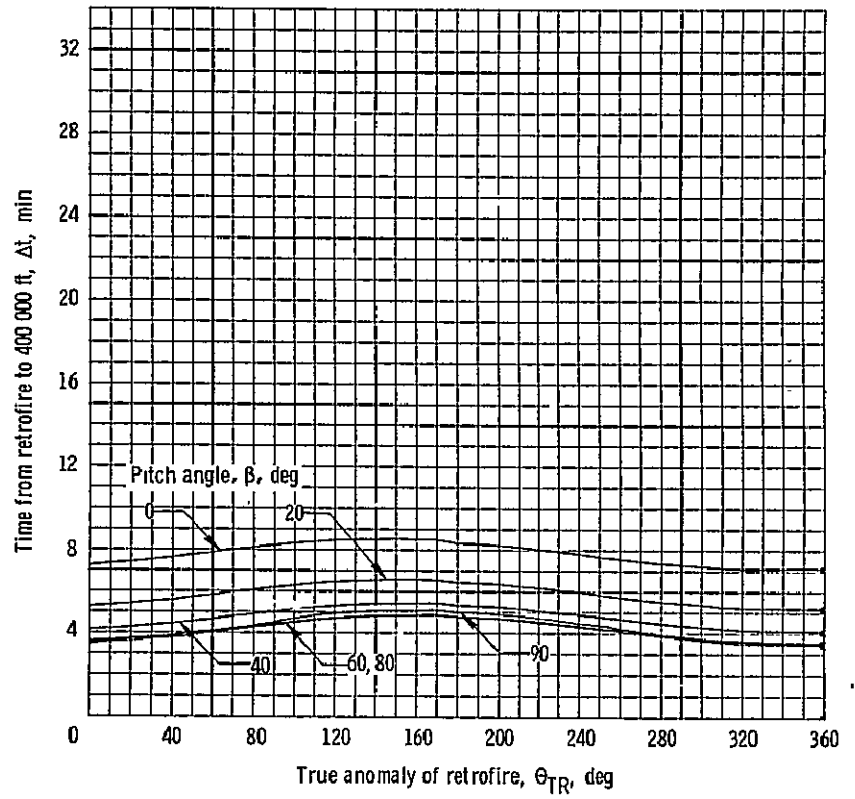
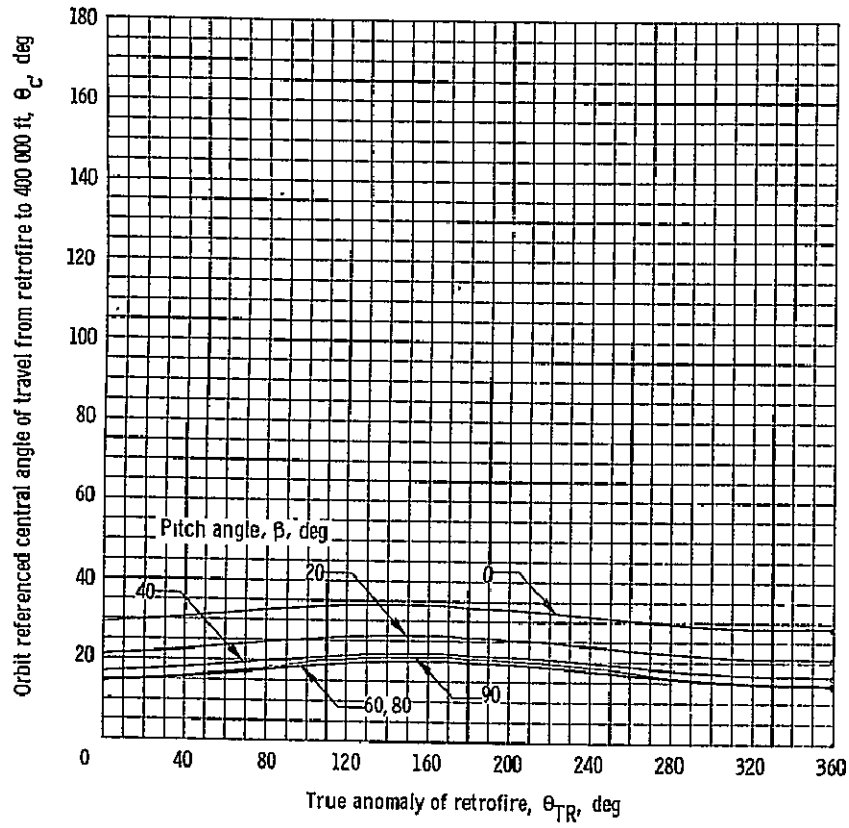
(b) Retrograde $\Delta V = 300$ fps.

Figure 10. - Continued.



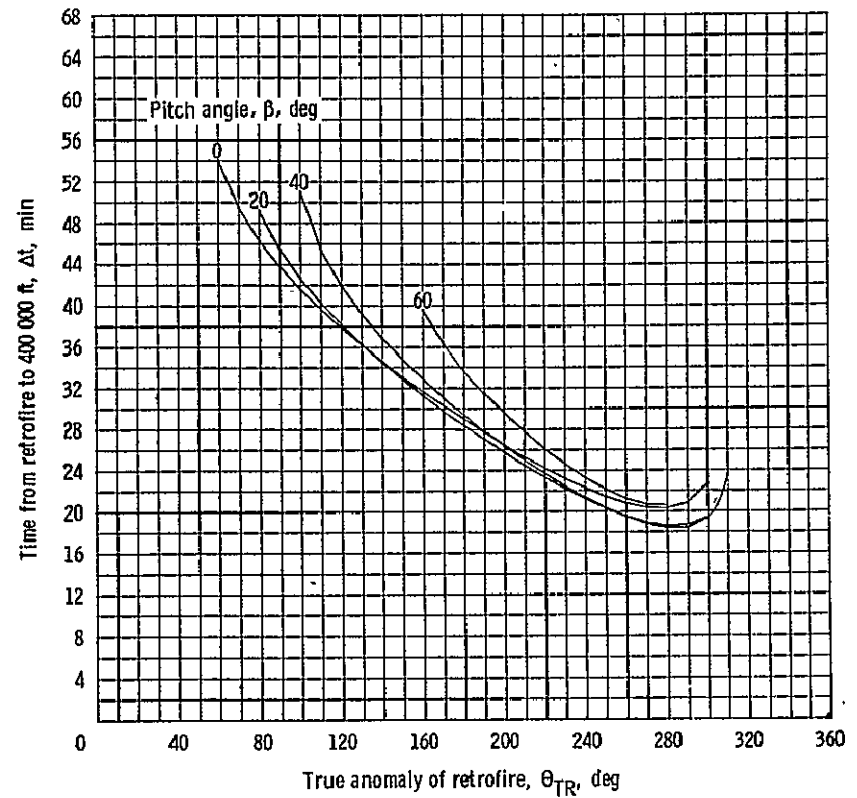
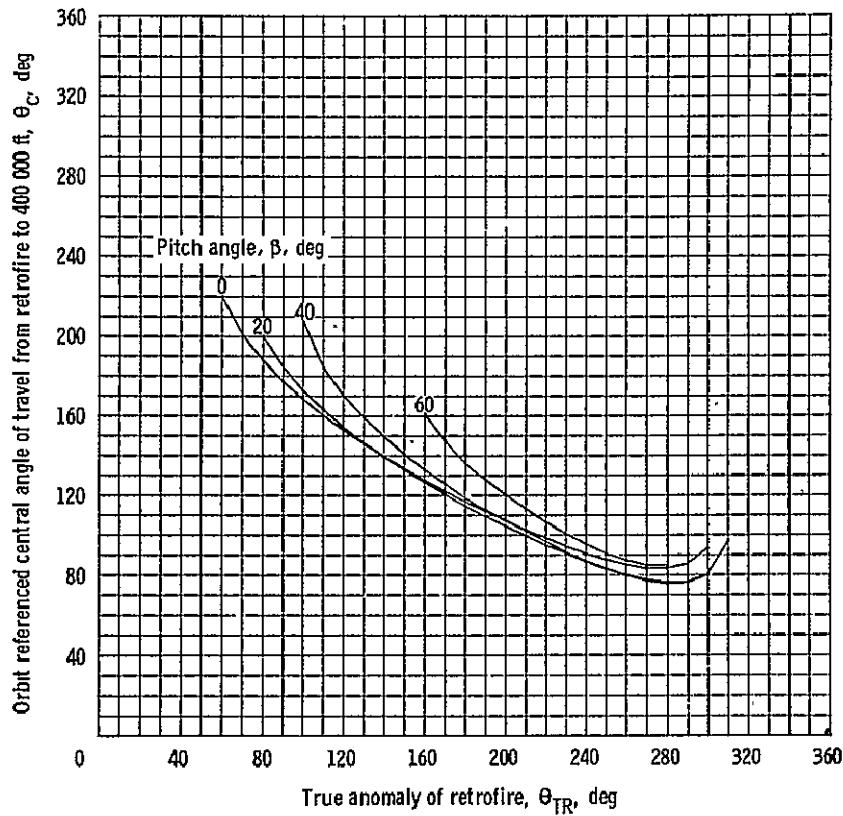
(c) Retrograde $\Delta V = 500$ fps.

Figure 10. - Continued.



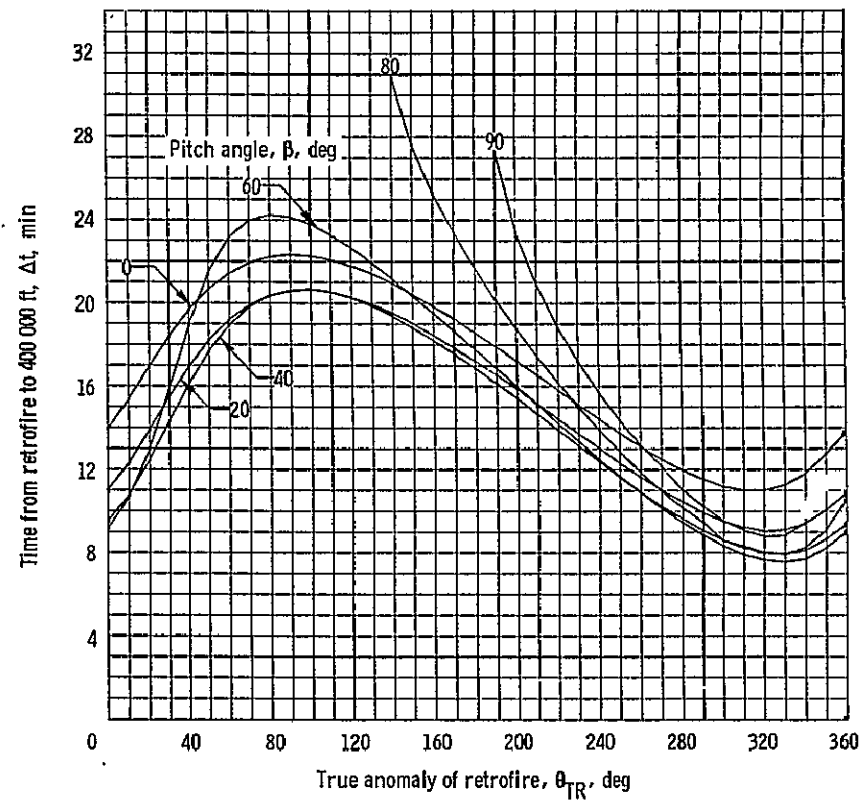
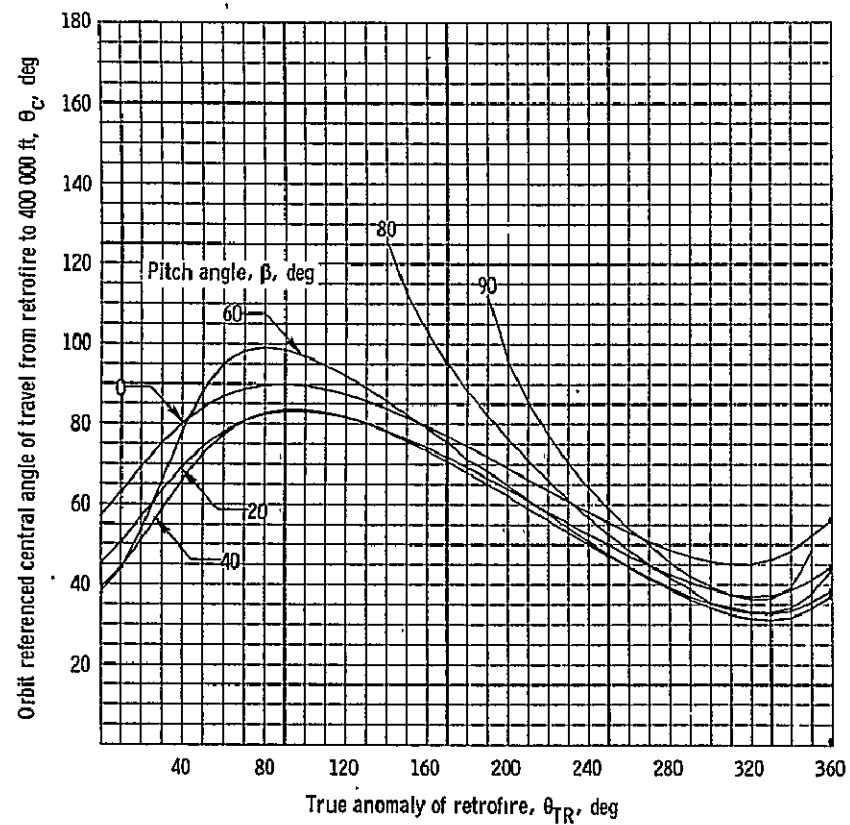
(d) Retrograde $\Delta V = 700$ fps.

Figure 10. - Concluded.



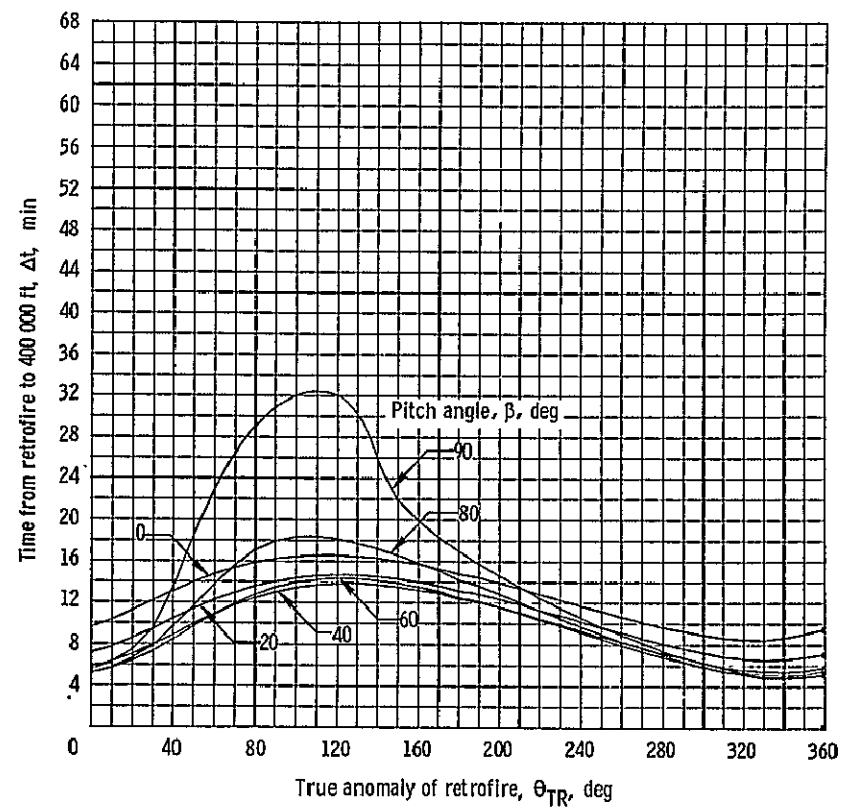
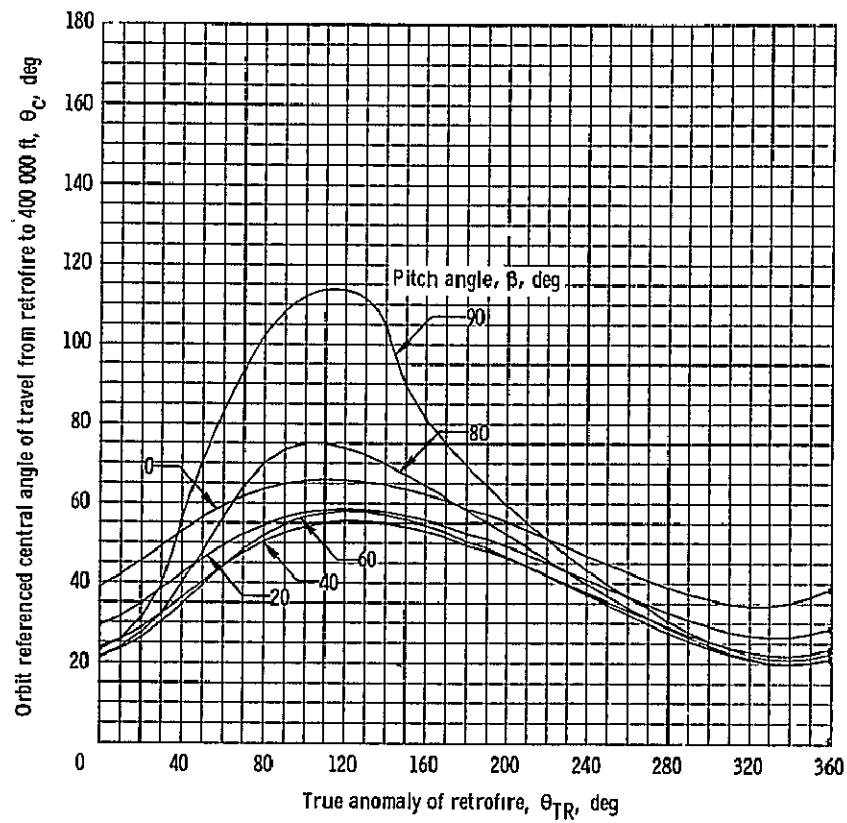
(a) Retrograde $\Delta V = 100$ fps.

Figure 11. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 150$ nautical miles and $h_p = 90$ nautical miles.



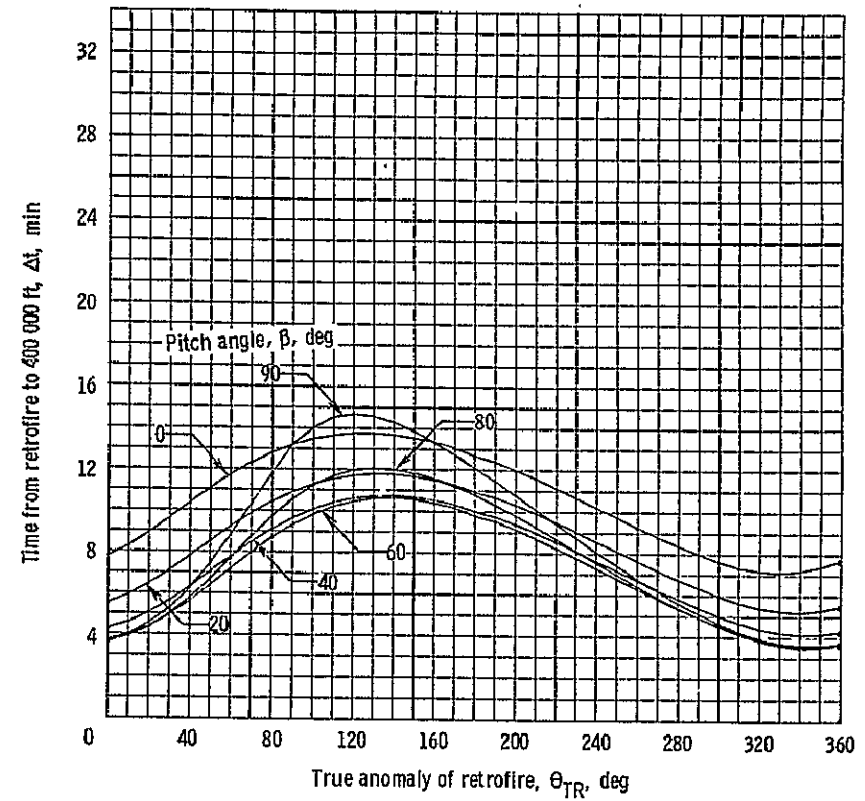
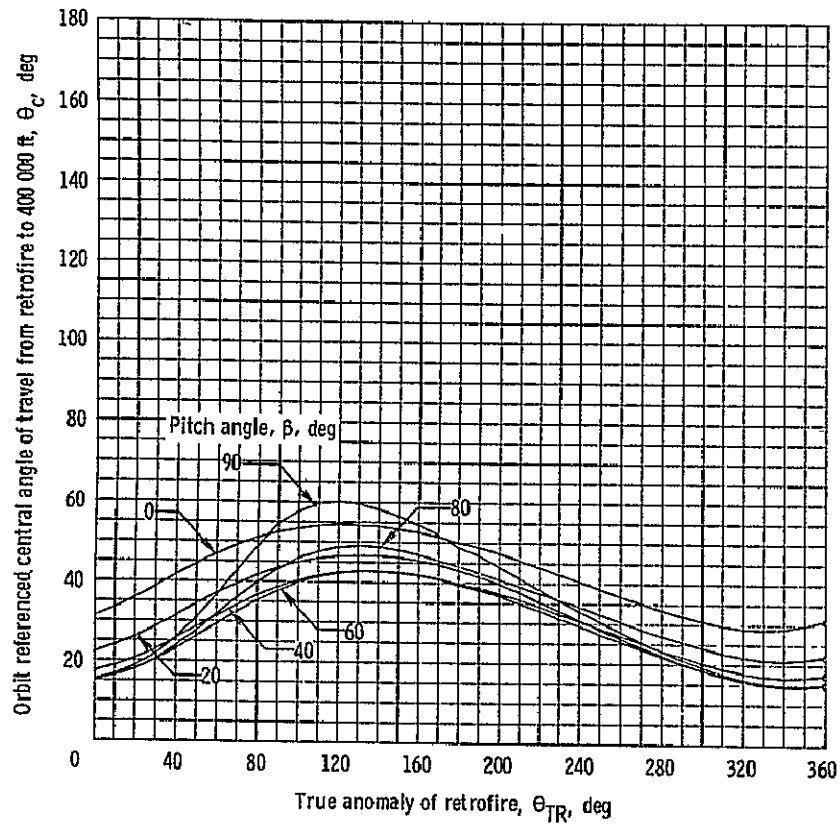
(b) Retrograde $\Delta V = 300$ fps.

Figure 11. - Continued.



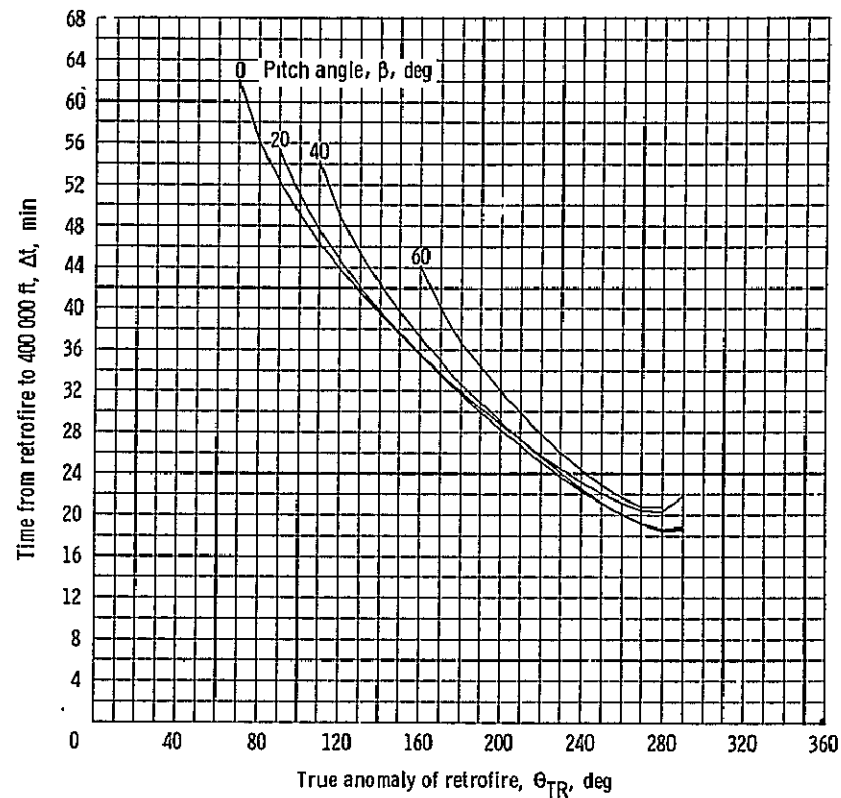
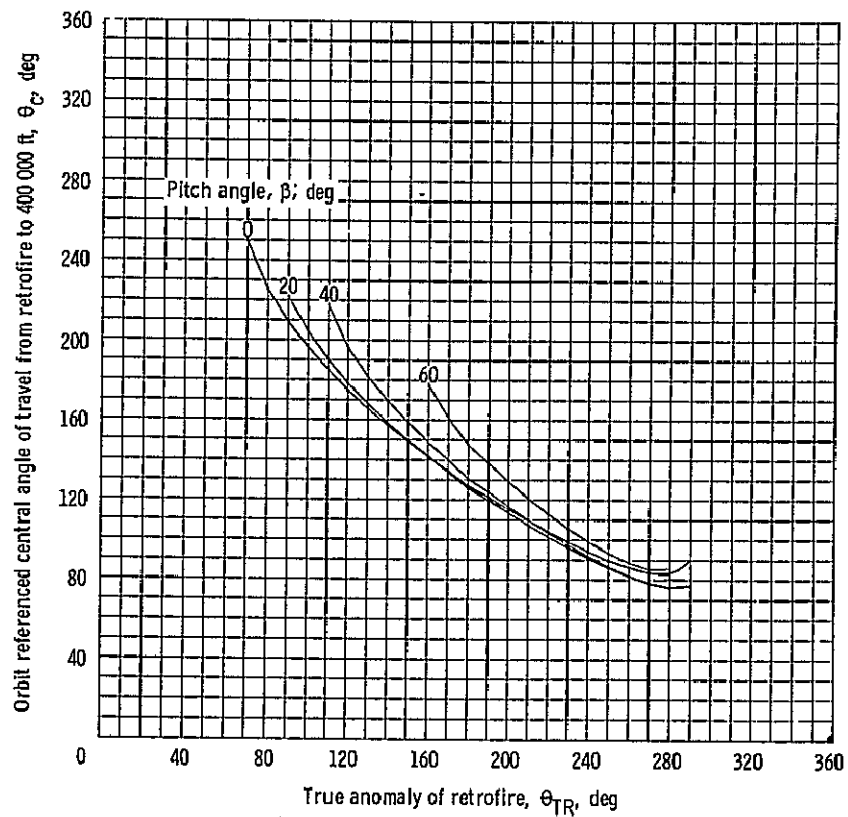
(c) Retrograde $\Delta V = 500$ fps.

Figure 11. - Continued.



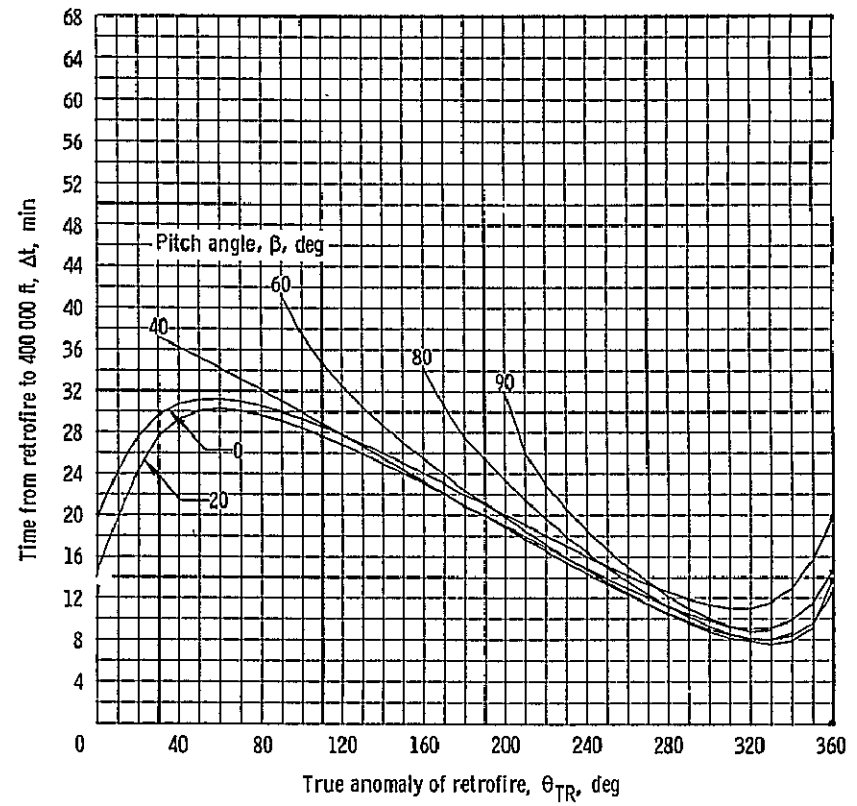
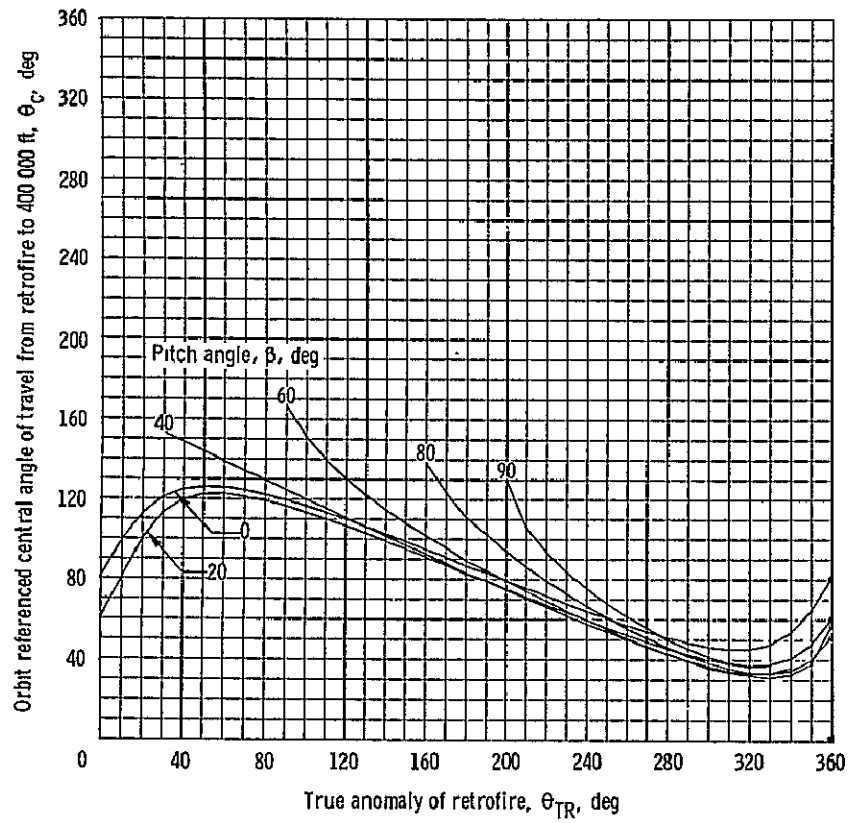
(d) Retrograde $\Delta V = 700$ fps.

Figure 11. - Concluded.



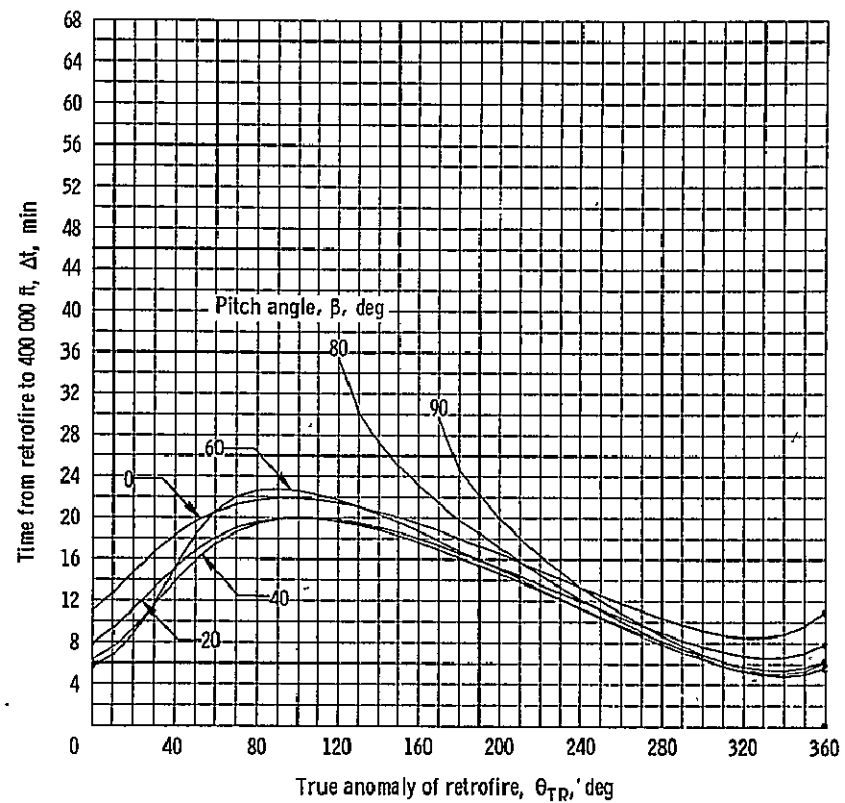
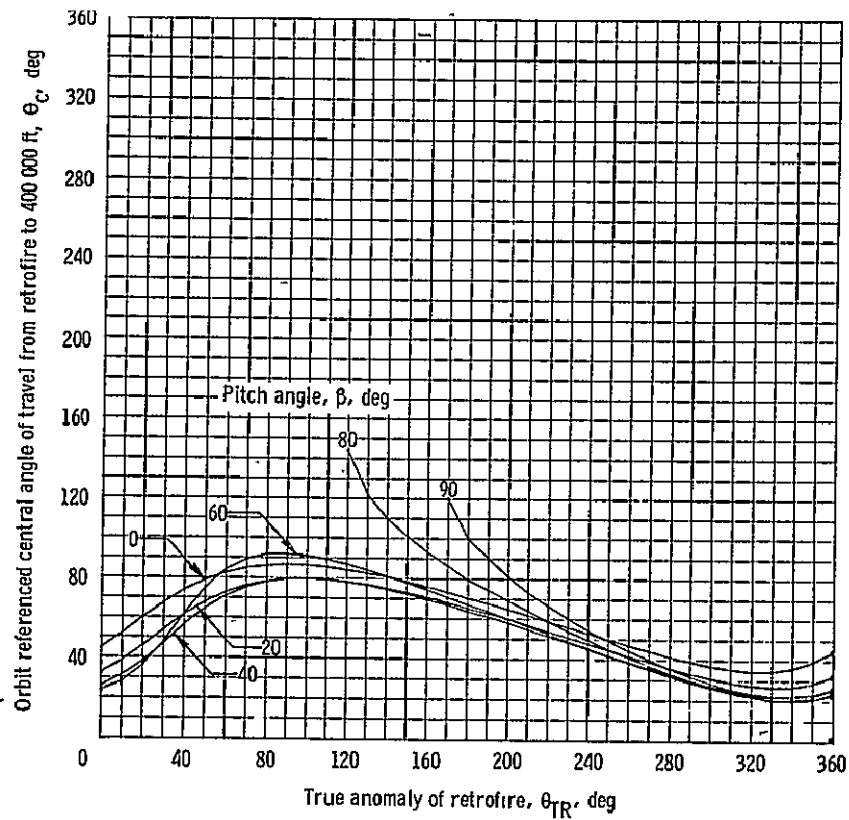
(a) Retrograde $\Delta V = 100$ fps.

Figure 12. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 200$ nautical miles and $h_p = 90$ nautical miles.



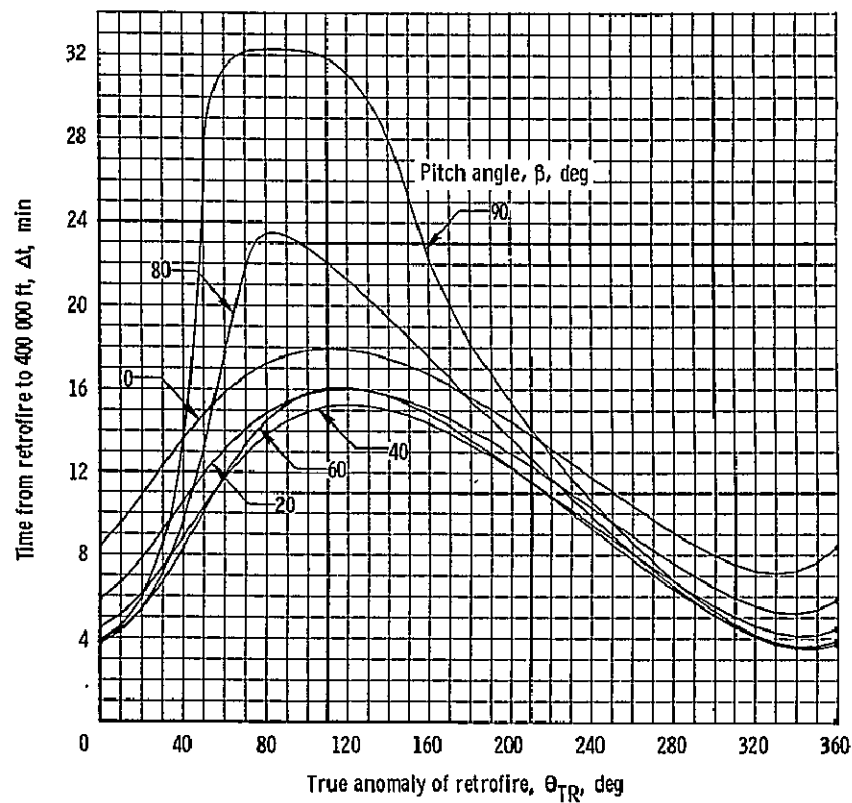
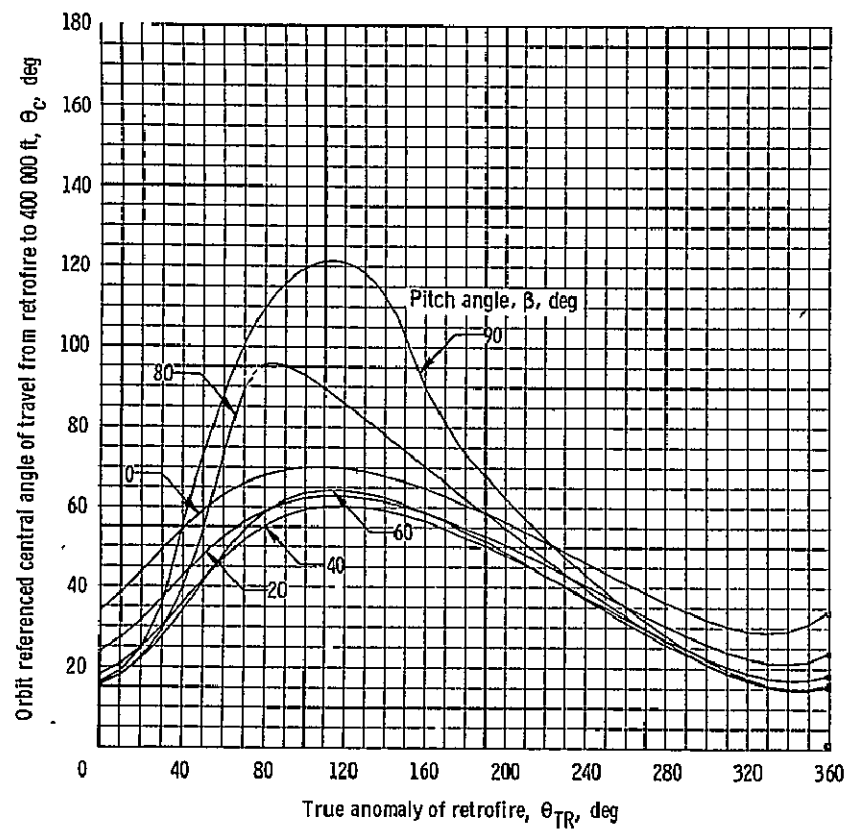
(b) Retrograde $\Delta V = 300$ fps.

Figure 12. - Continued.



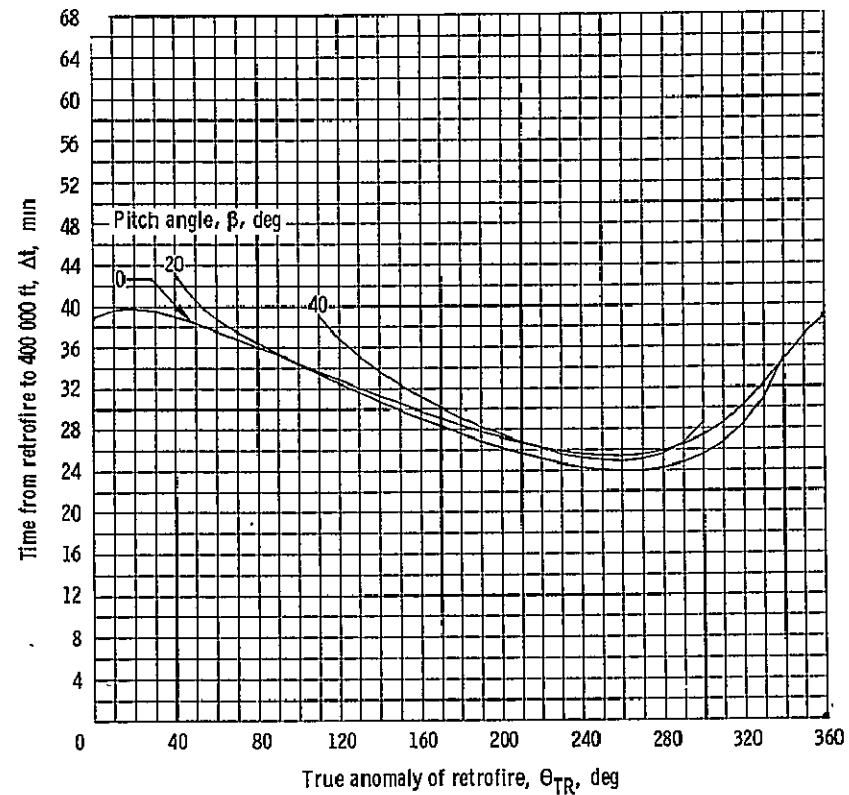
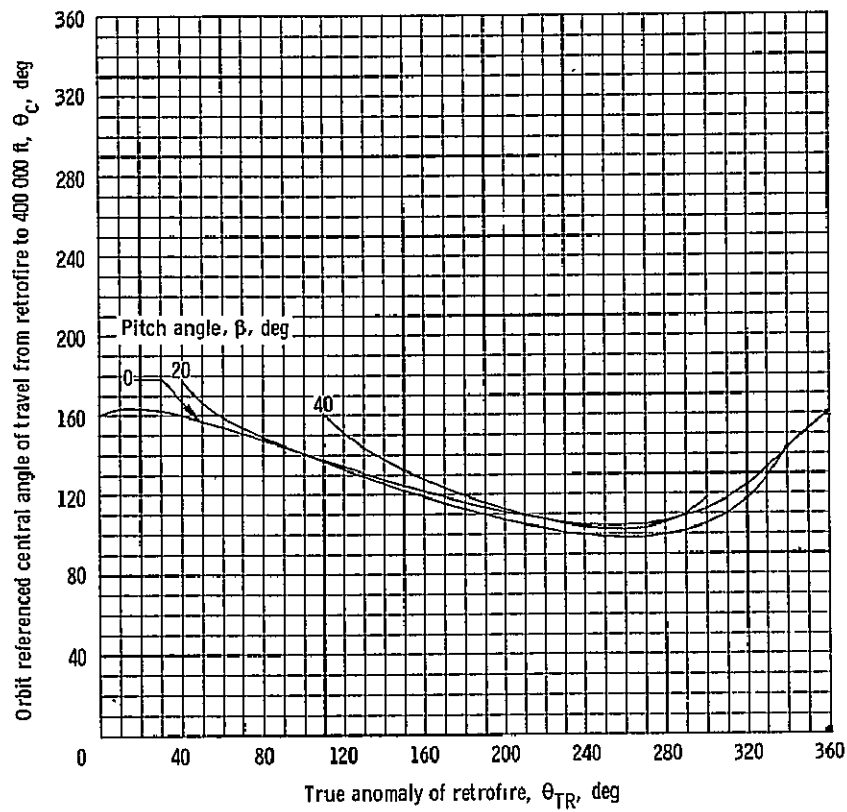
(c) Retrograde $\Delta V = 500$ fps.

Figure 12. - Continued.



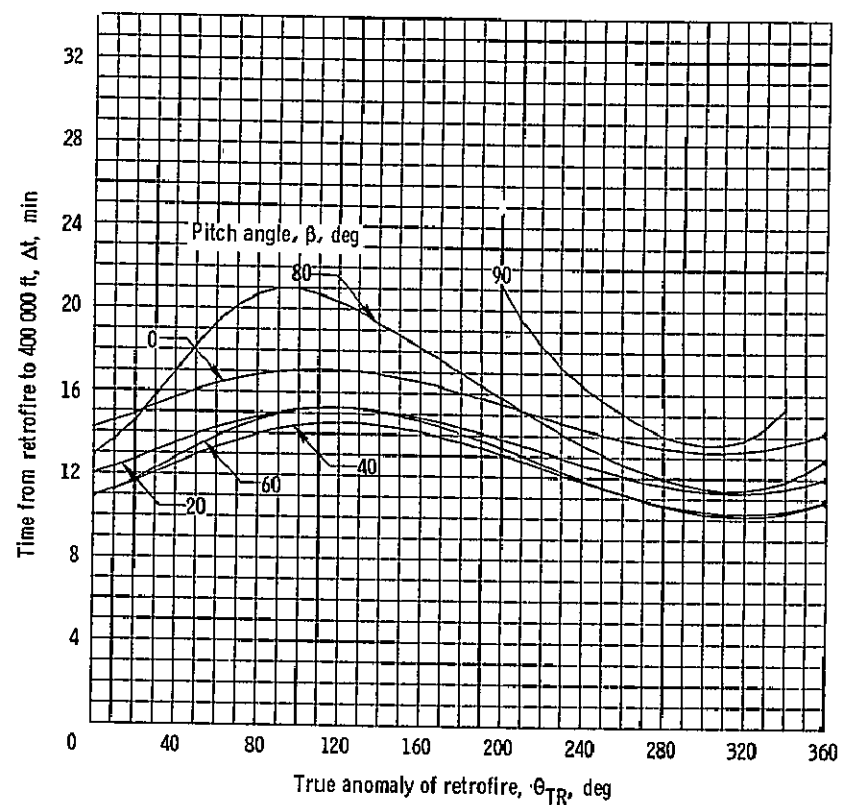
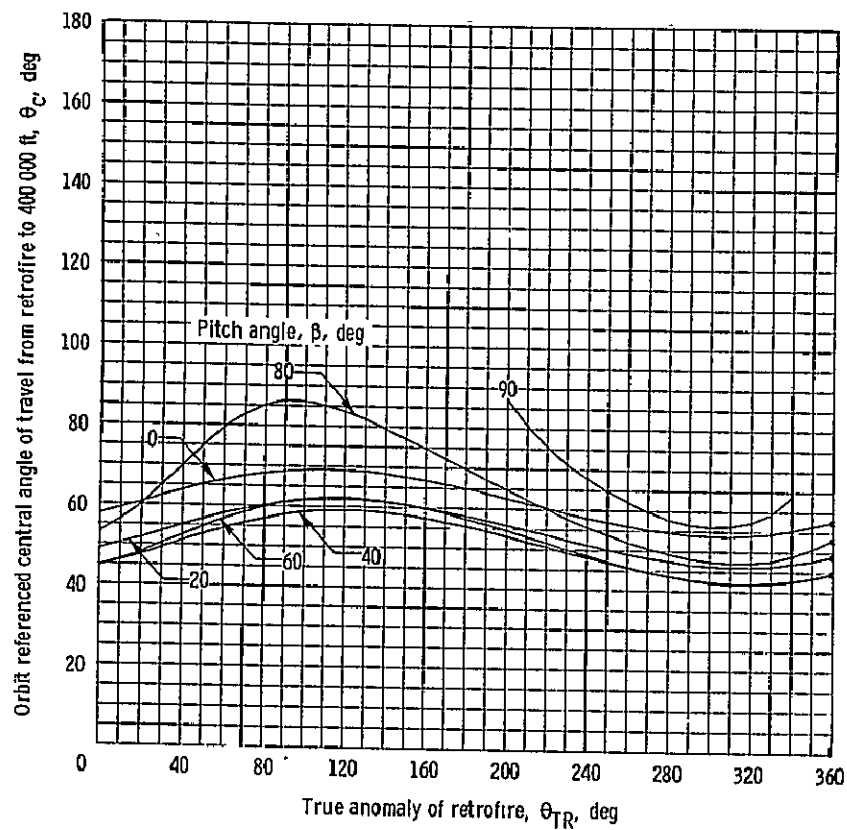
(d) Retrograde $\Delta V = 700$ fps.

Figure 12.- Concluded.



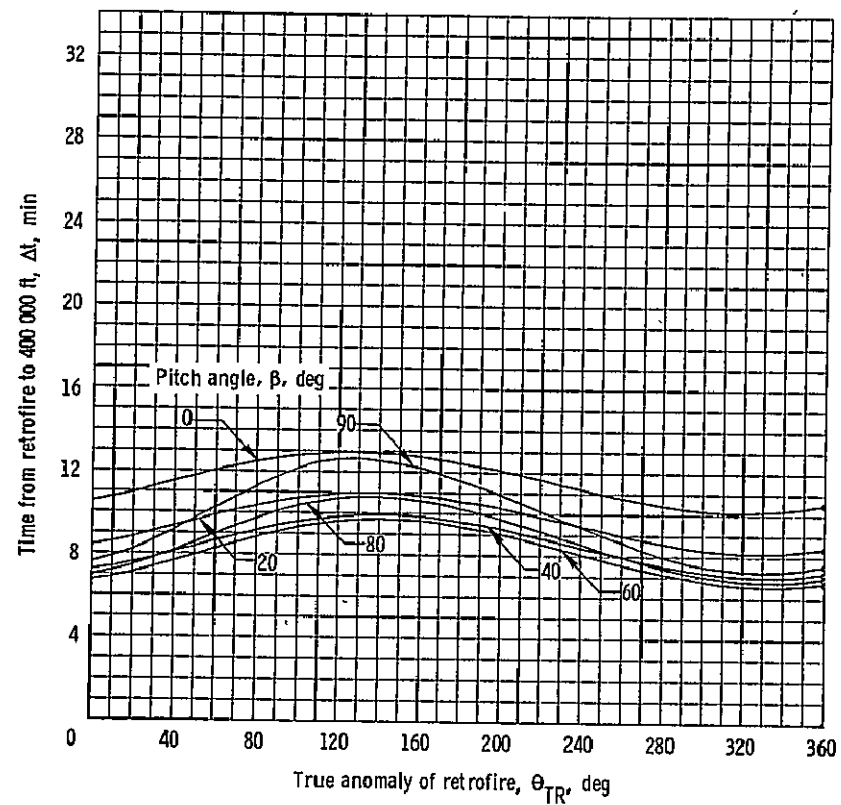
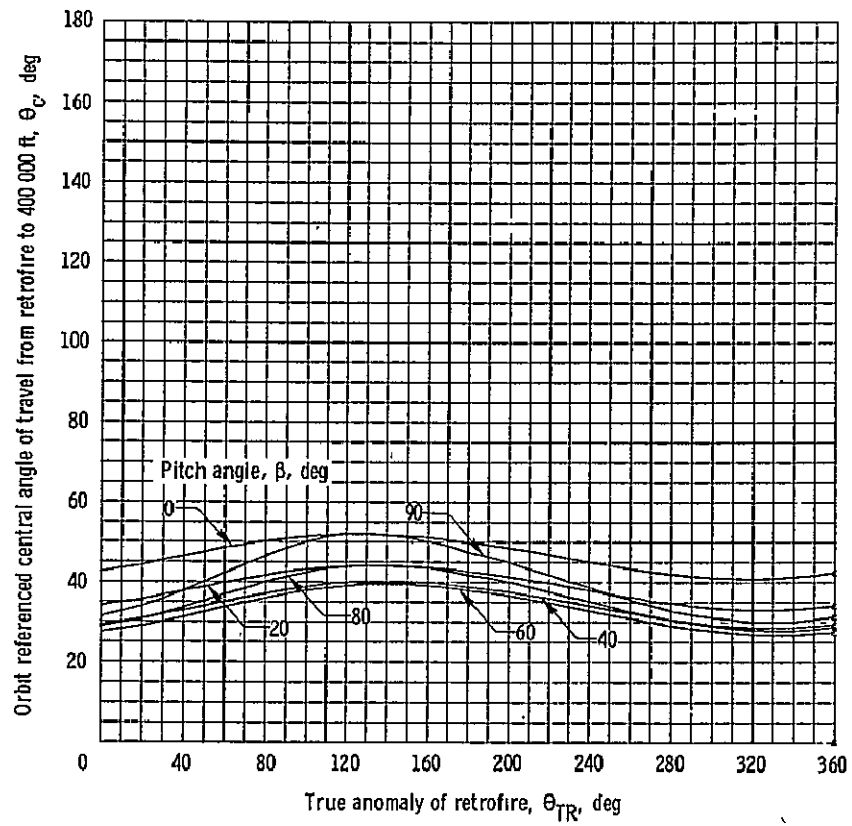
(a) Retrograde $\Delta V = 100$ fps.

Figure 13. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 120$ nautical miles and $h_p = 100$ nautical miles.



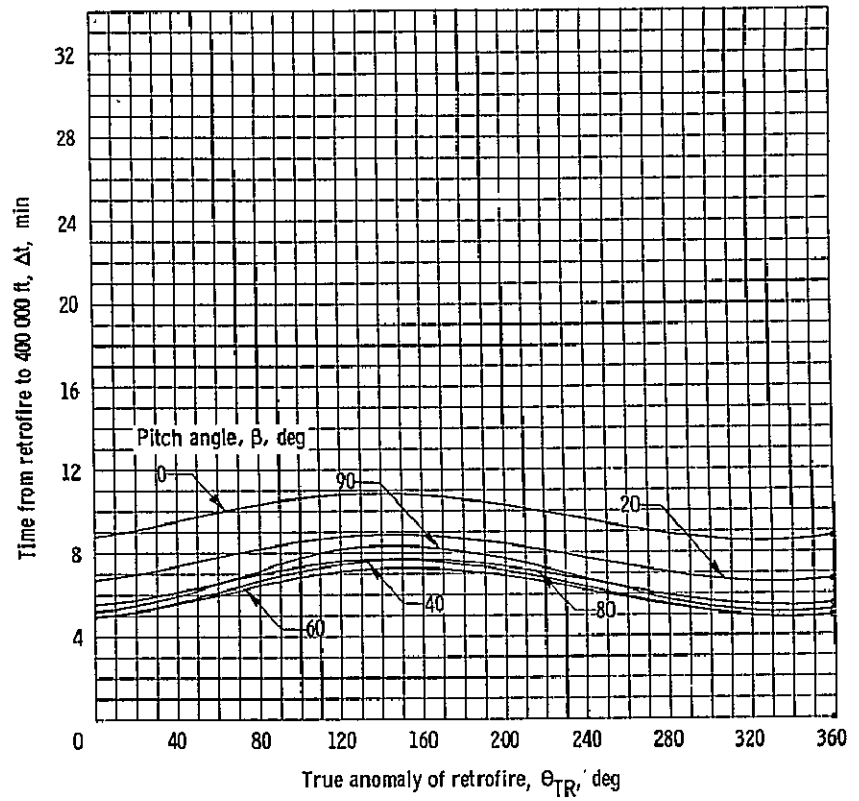
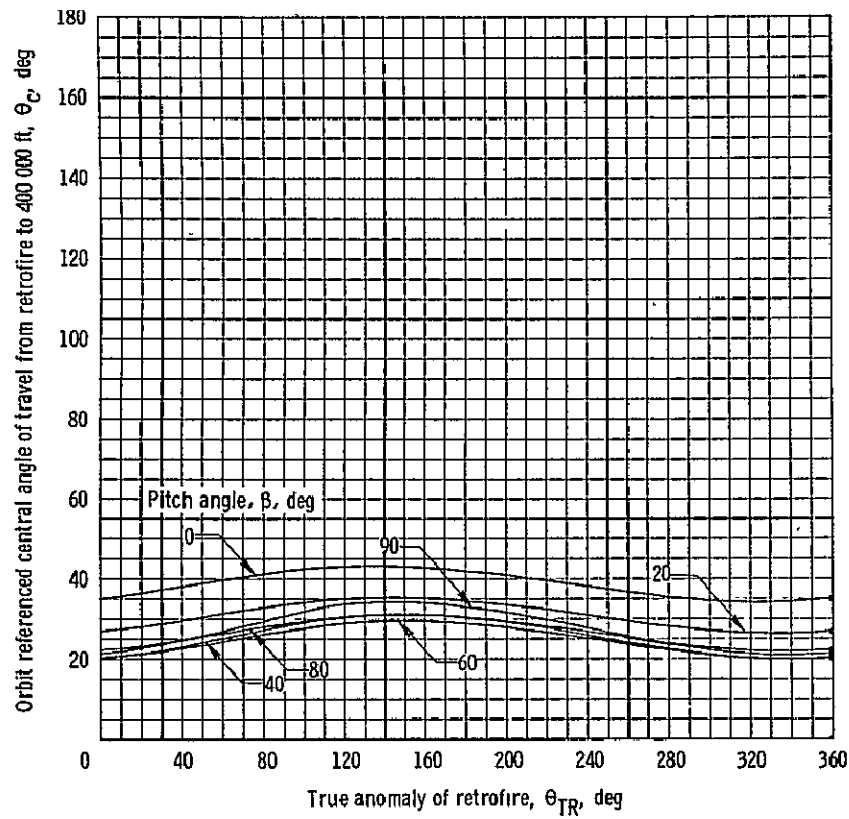
(b) Retrograde $\Delta V = 300$ fps.

Figure 13. - Continued.



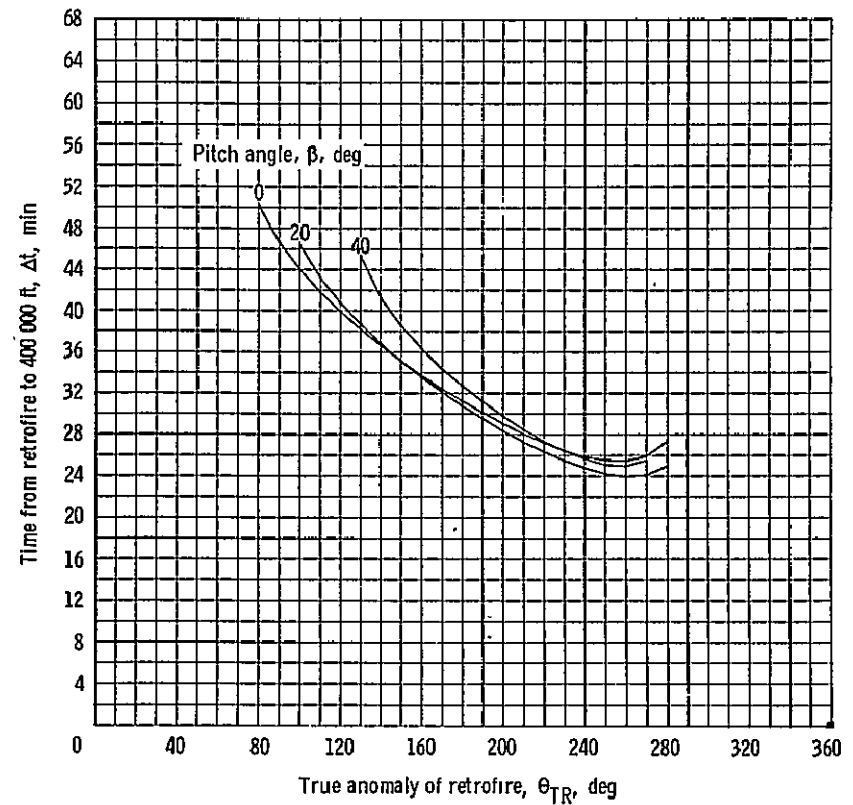
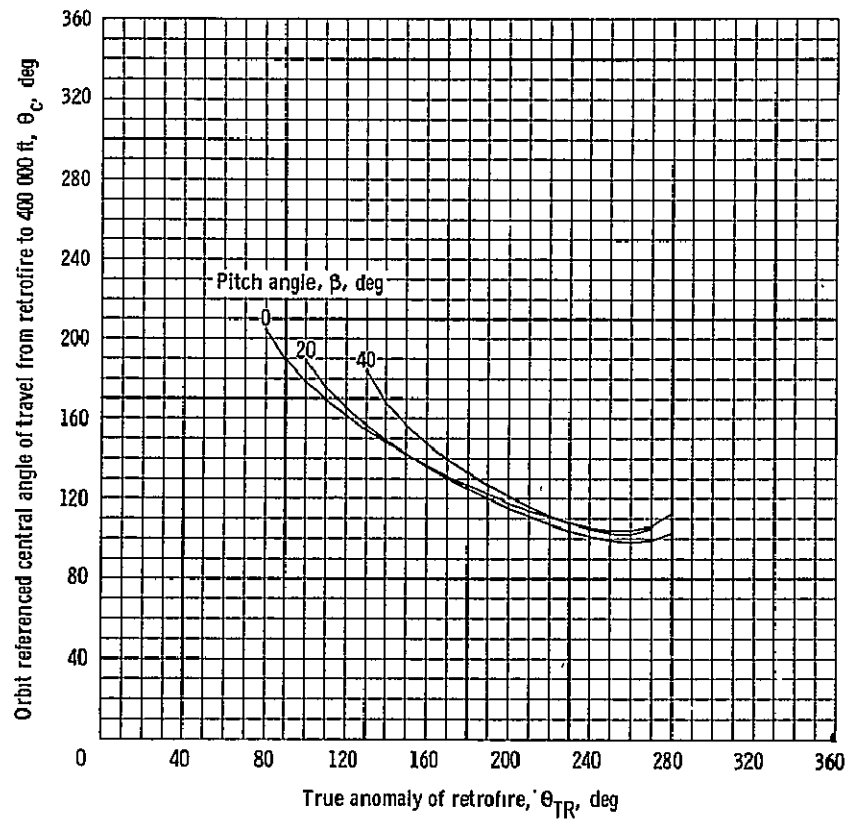
(c) Retrograde $\Delta V = 500$ fps.

Figure 13. - Continued.



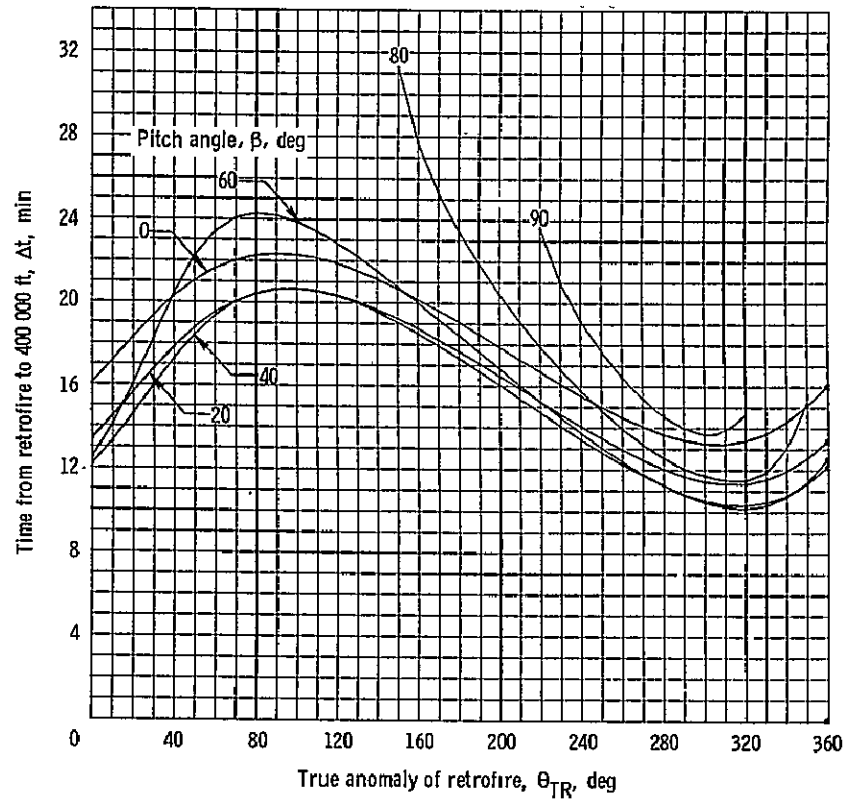
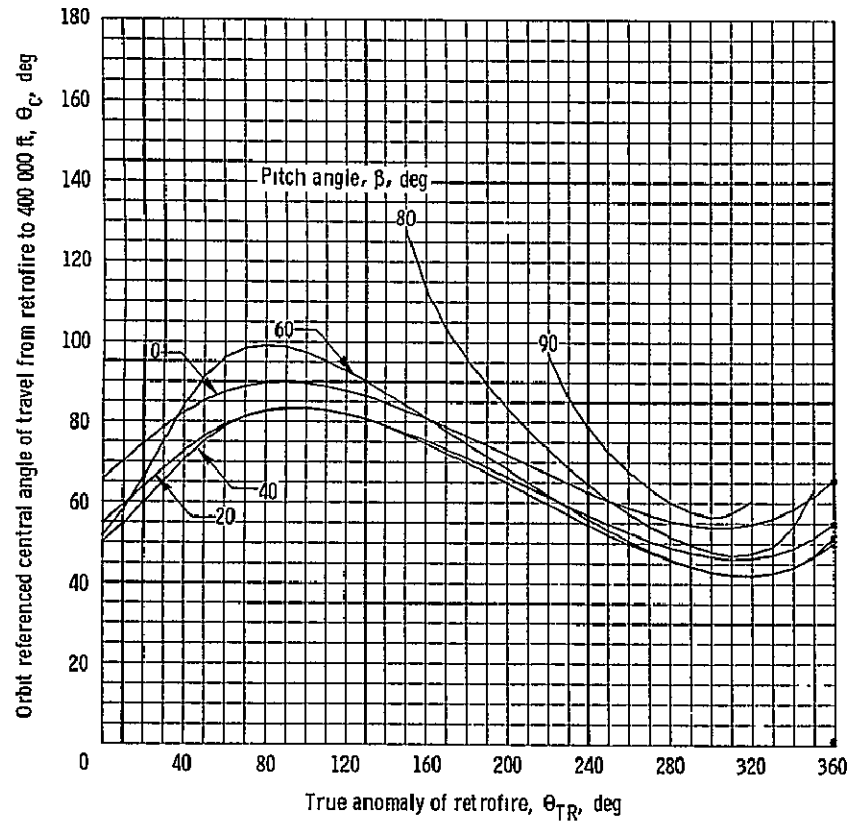
(d) Retrograde $\Delta V = 700$ fps.

Figure 13. - Concluded.



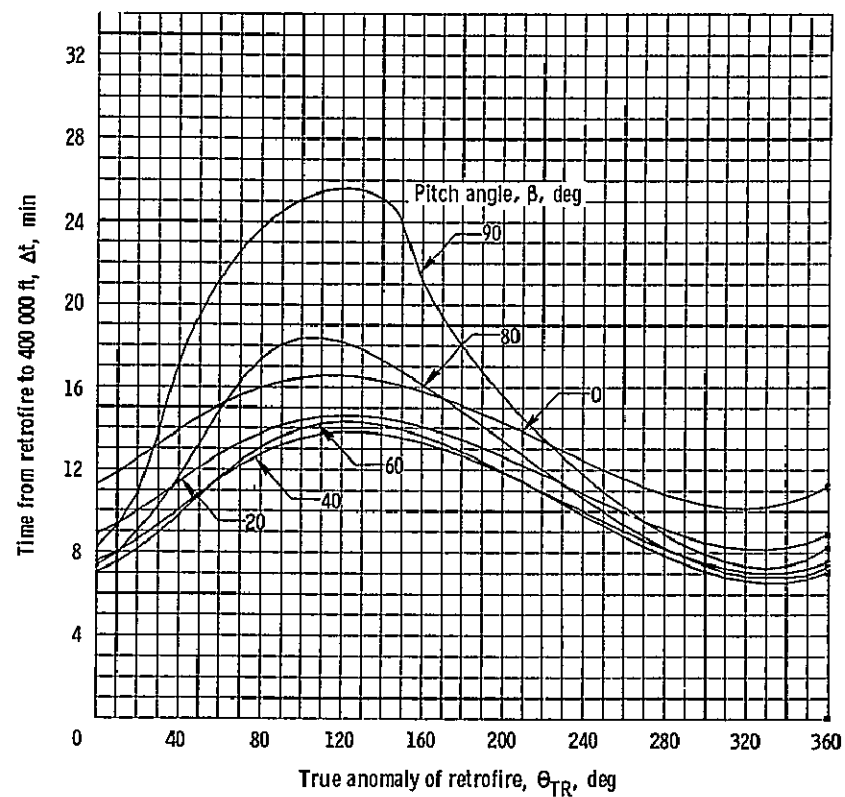
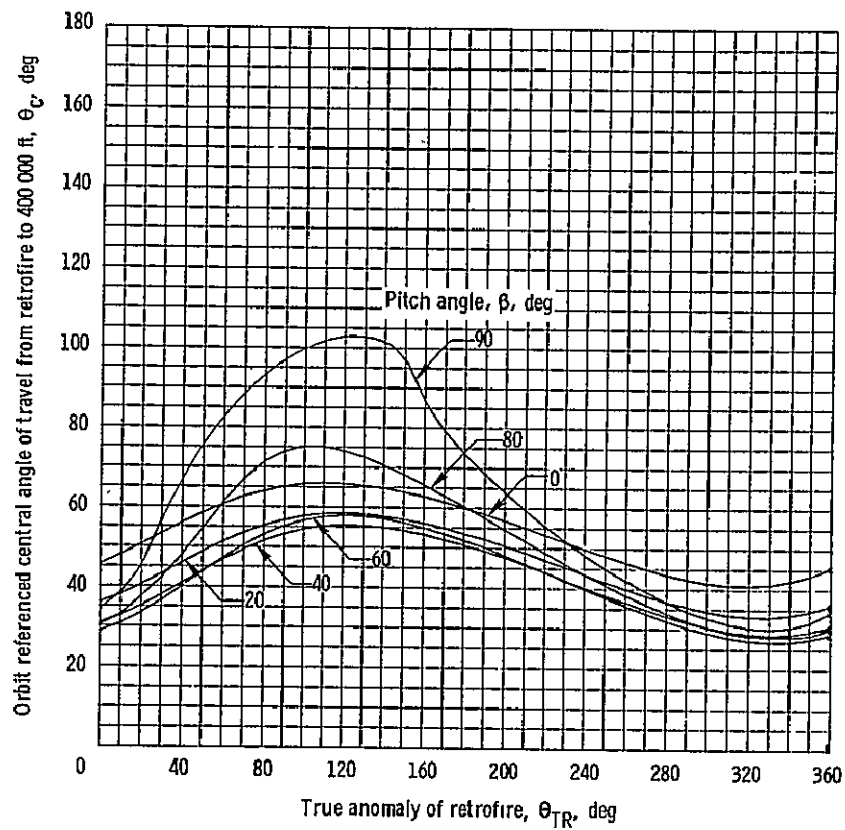
(a) Retrograde $\Delta V = 100$ fps.

Figure 14. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 150$ nautical miles and $h_p = 100$ nautical miles.



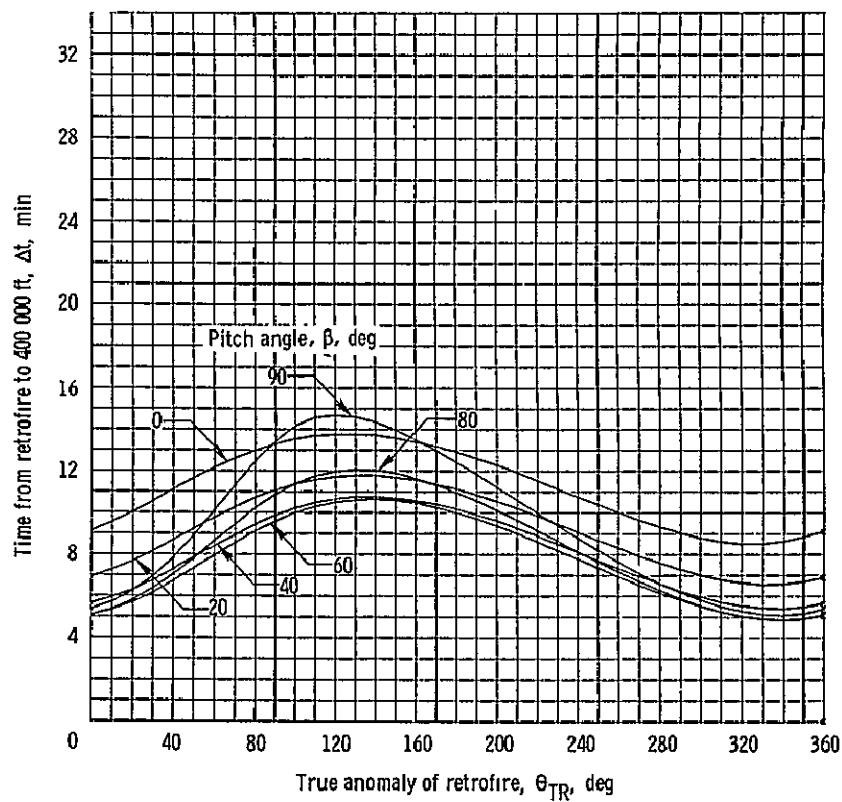
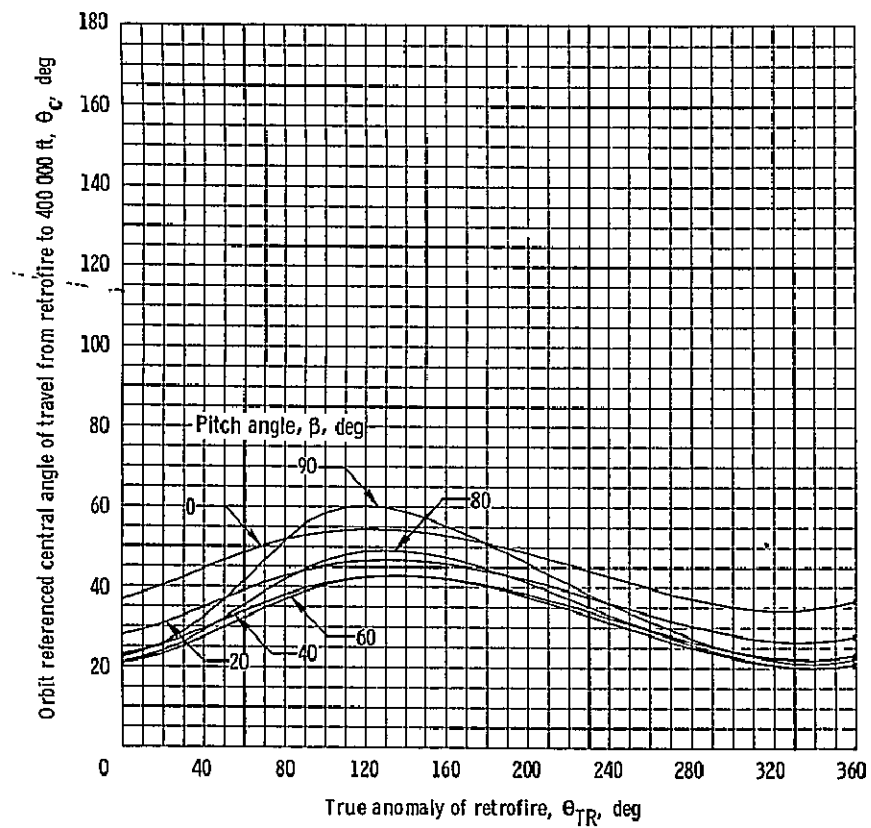
(b) Retrograde $\Delta V = 300$ fps.

Figure 14.- Continued.



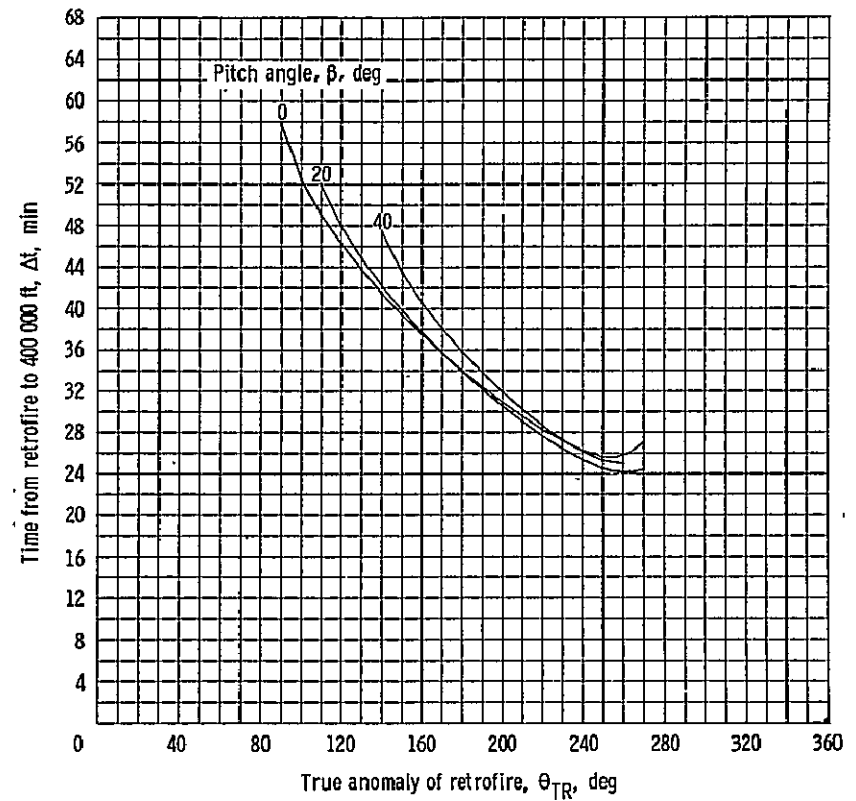
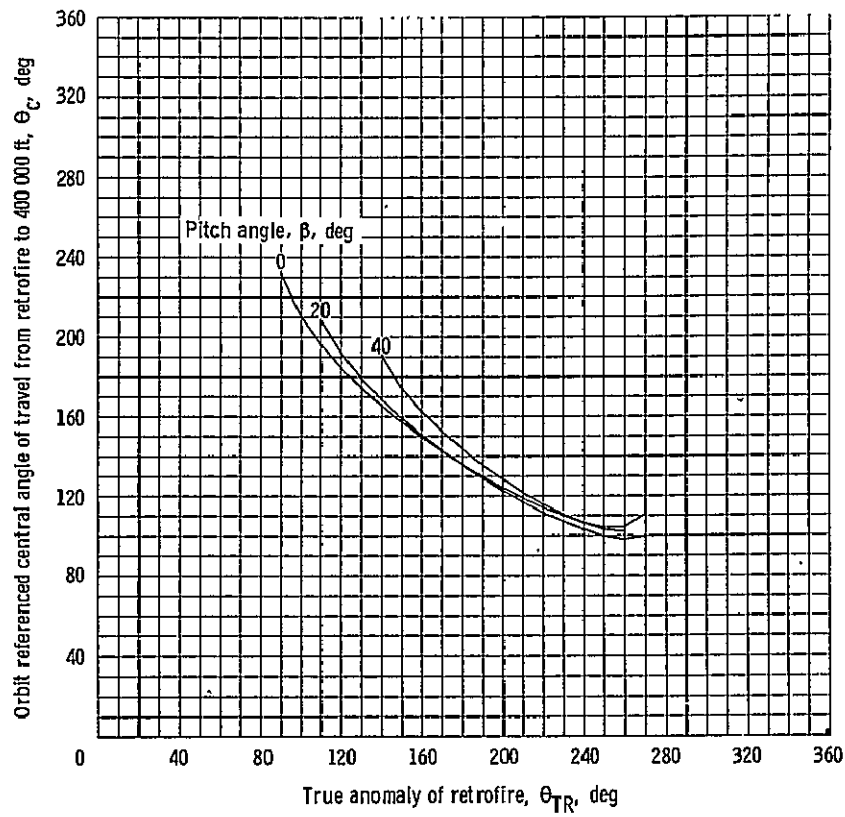
(c) Retrograde $\Delta V = 500$ fps.

Figure 14. - Continued.



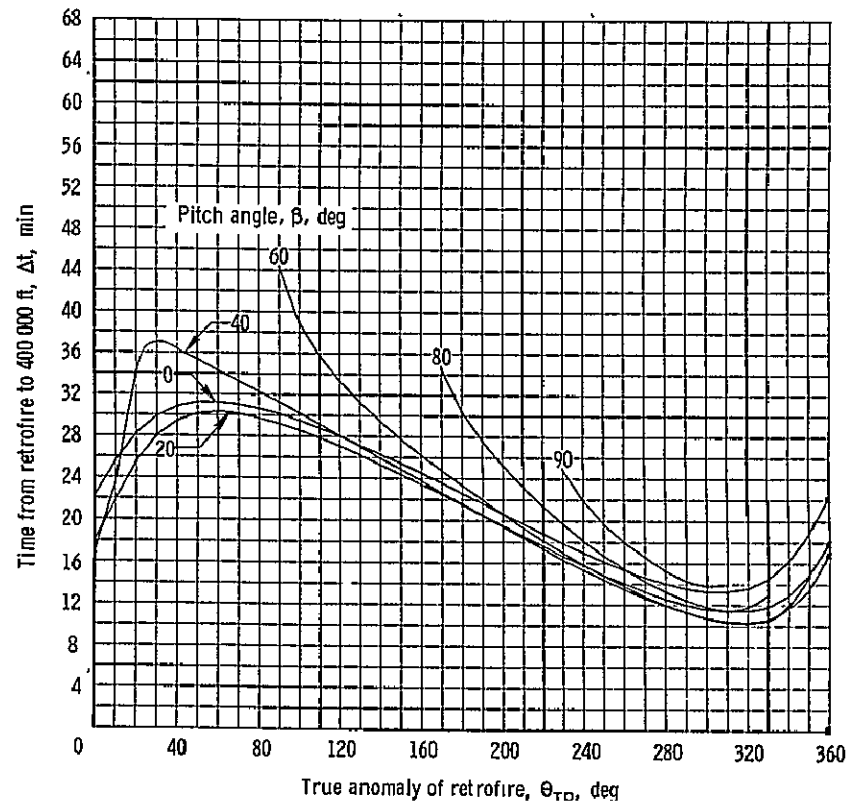
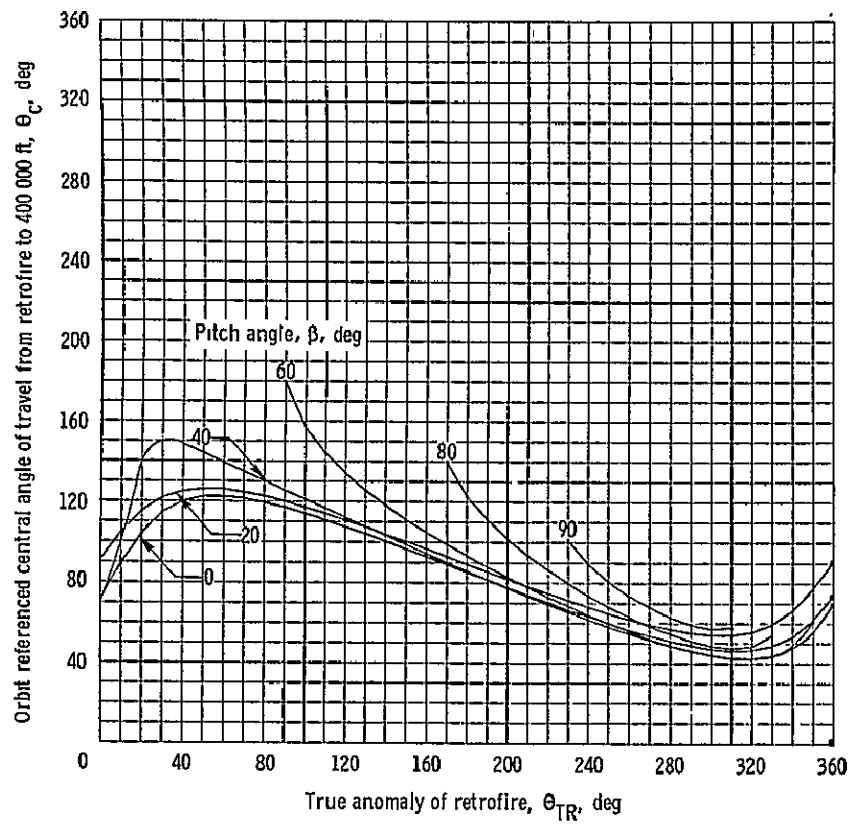
(d) Retrograde $\Delta V = 700$ fps.

Figure 14. - Concluded.



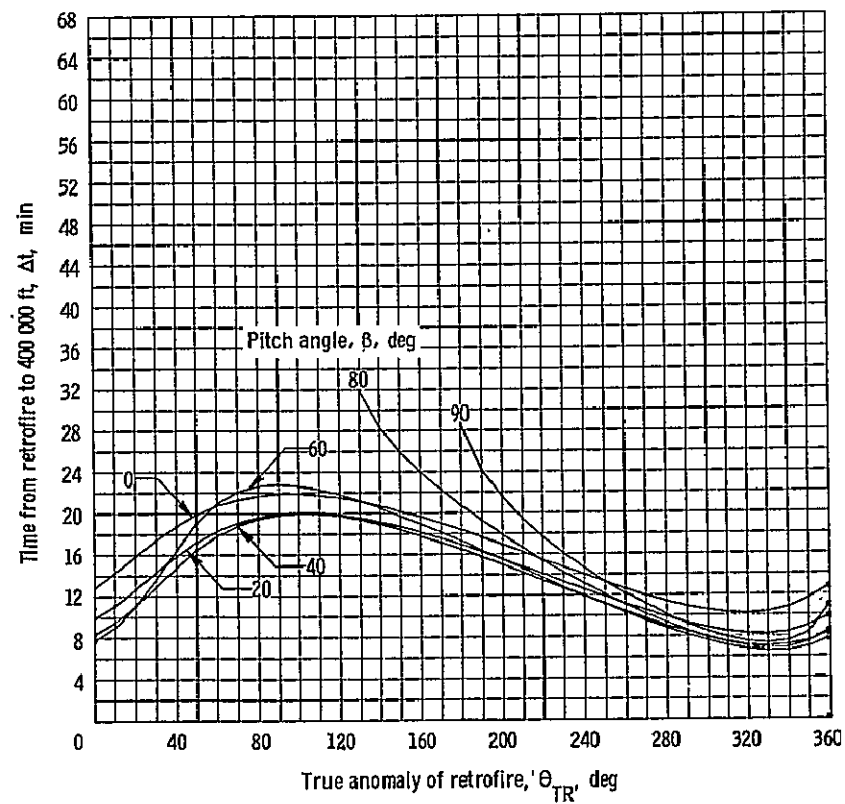
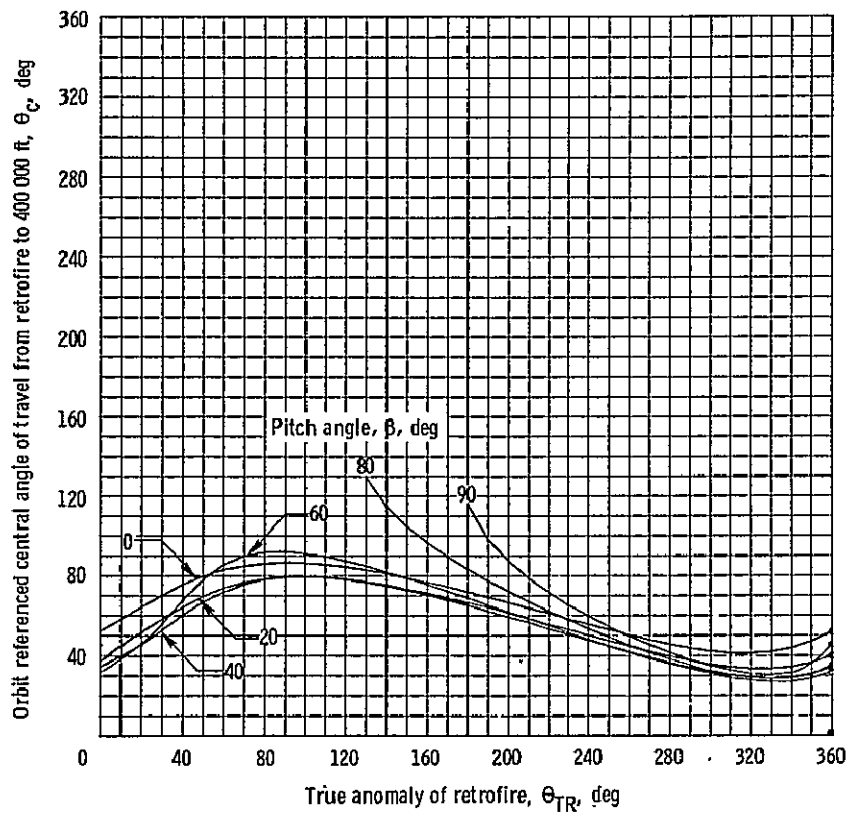
(a) Retrograde $\Delta V = 100$ fps.

Figure 15. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 200$ nautical miles and $h_p = 100$ nautical miles.



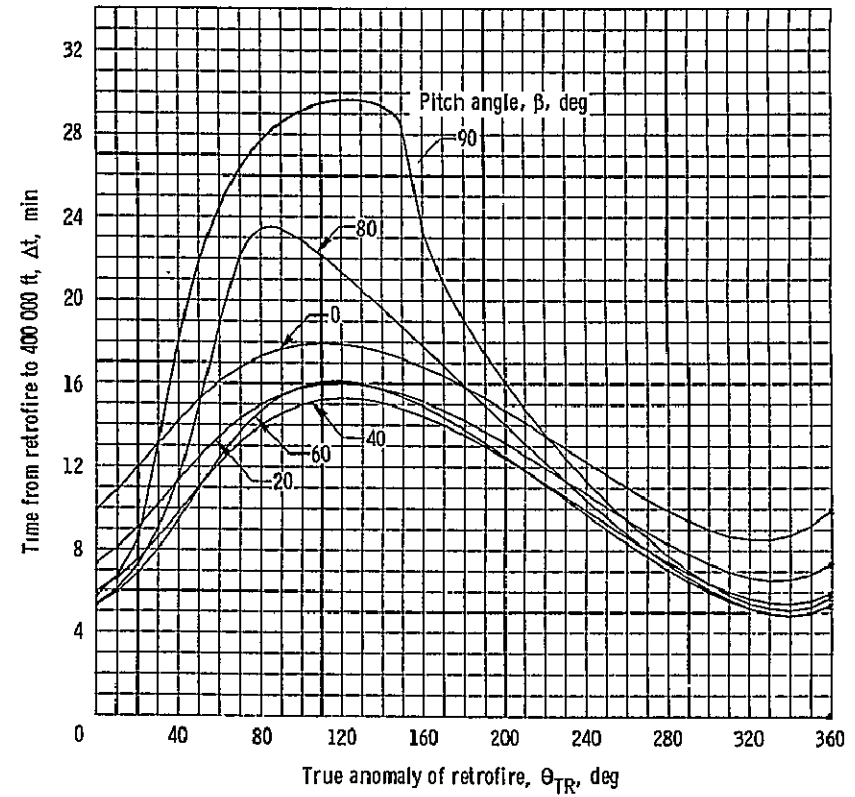
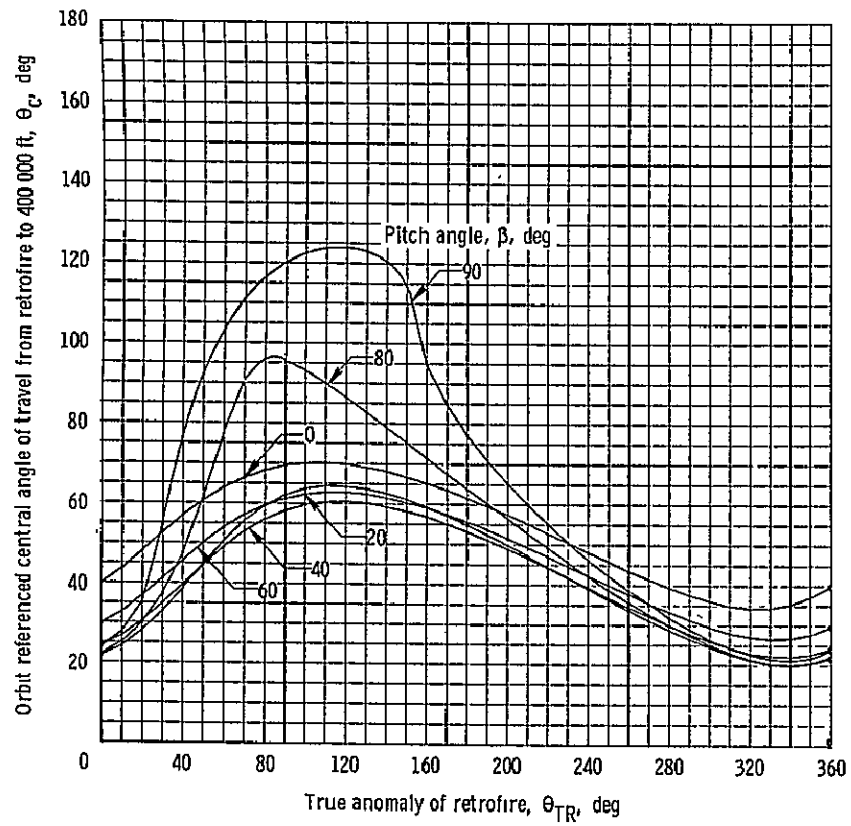
(b) Retrograde $\Delta V = 300$ fps.

Figure 15, - Continued.



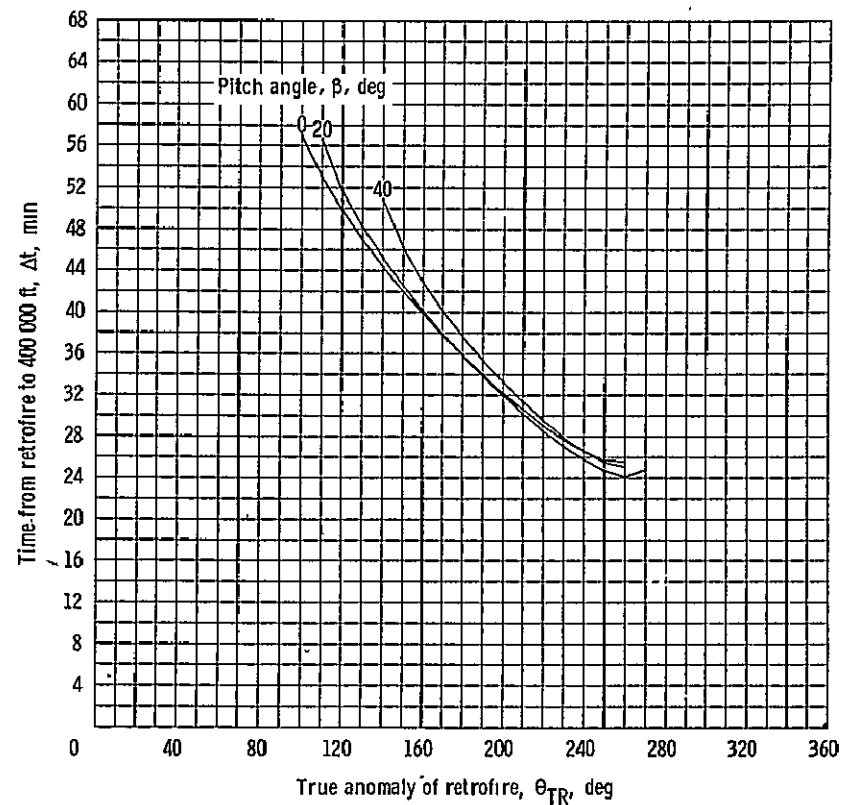
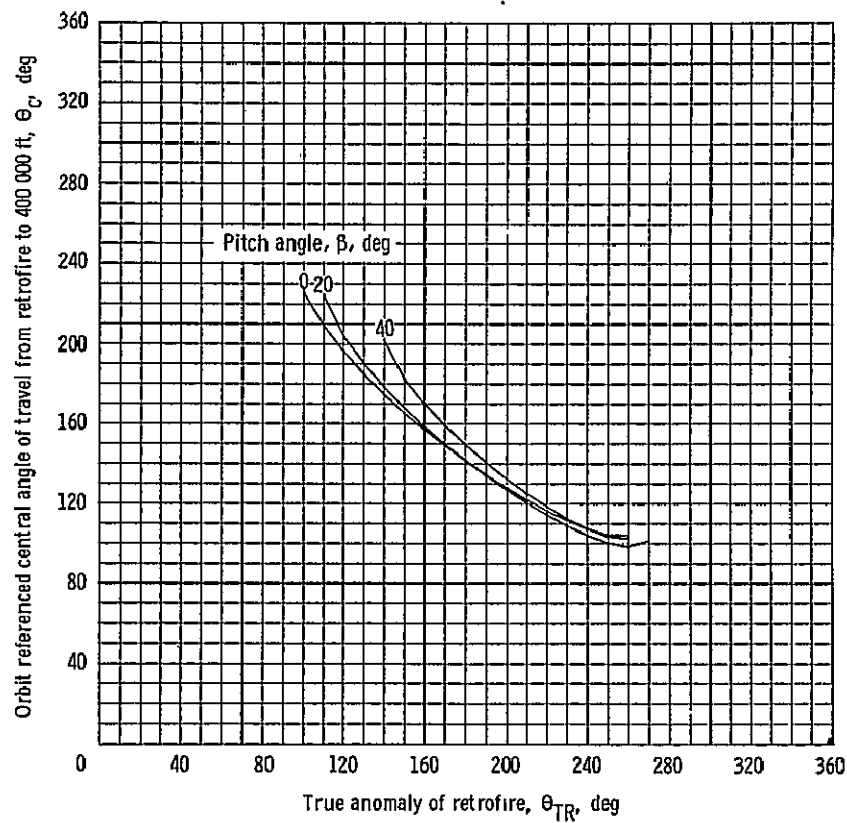
(c) Retrograde $\Delta V = 500$ fps.

Figure 15. - Continued.



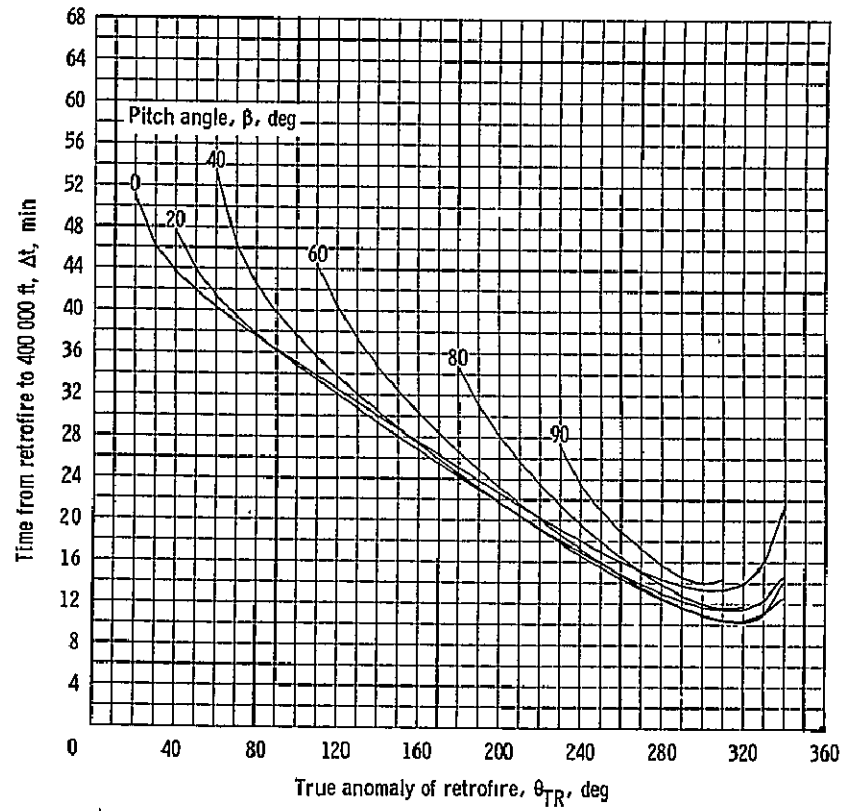
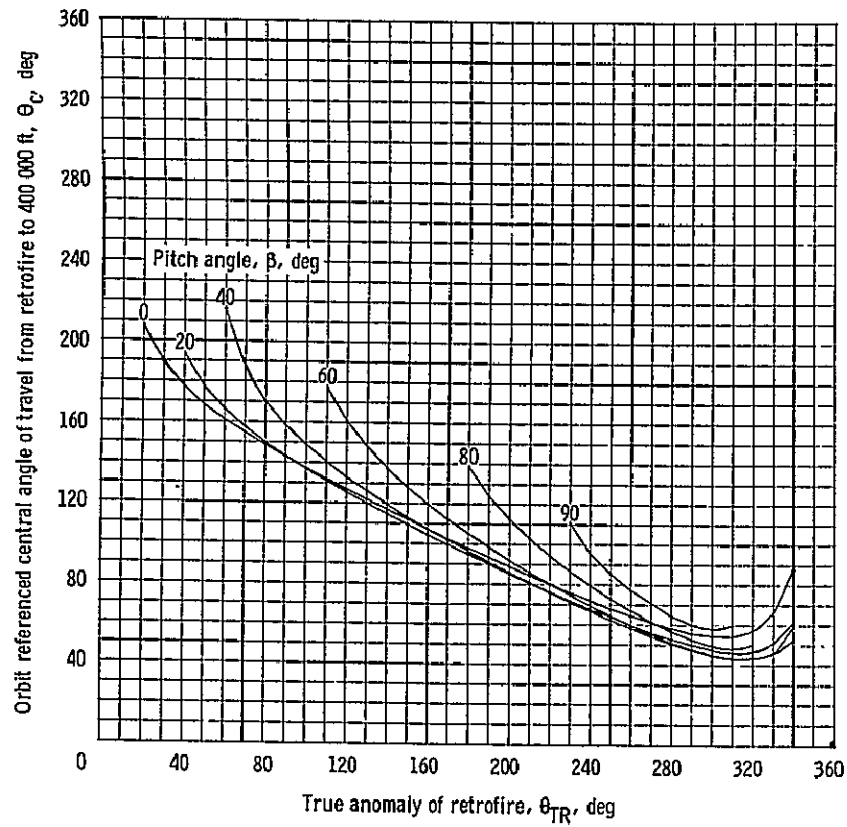
(d) Retrograde $\Delta V = 700$ fps.

Figure 15. - Concluded.



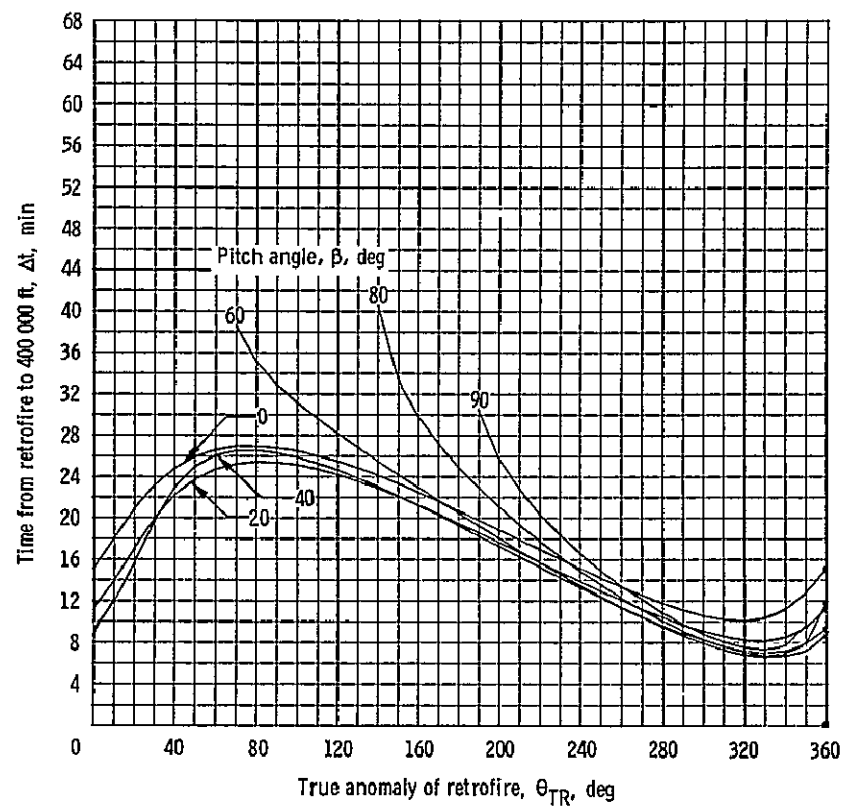
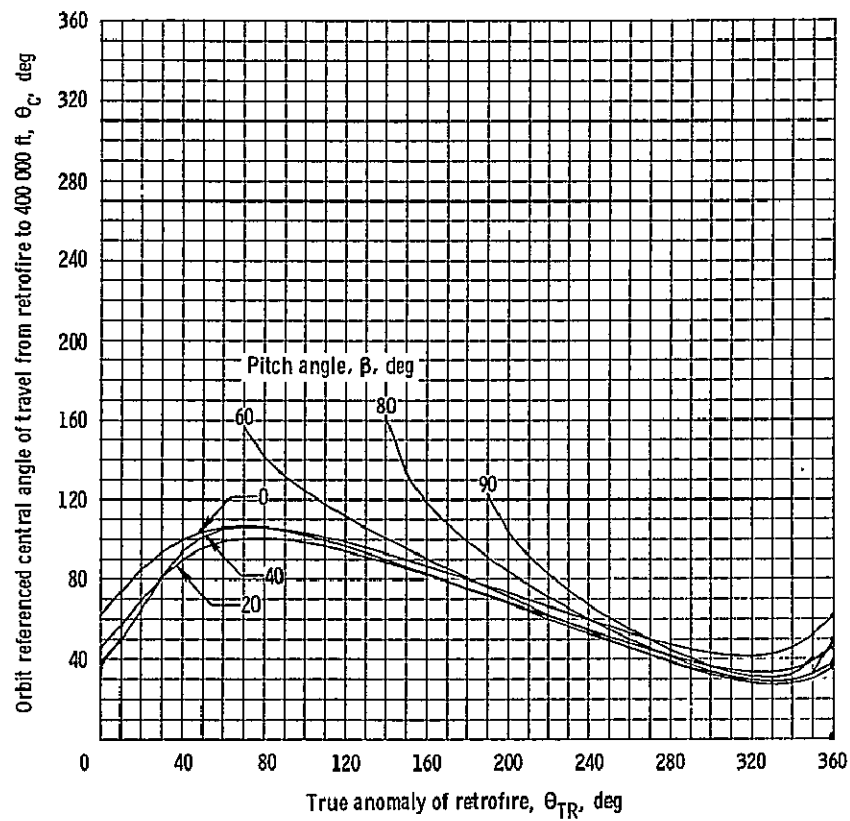
(a) Retrograde $\Delta V = 100$ fps.

Figure 16. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 250$ nautical miles and $h_p = 100$ nautical miles.



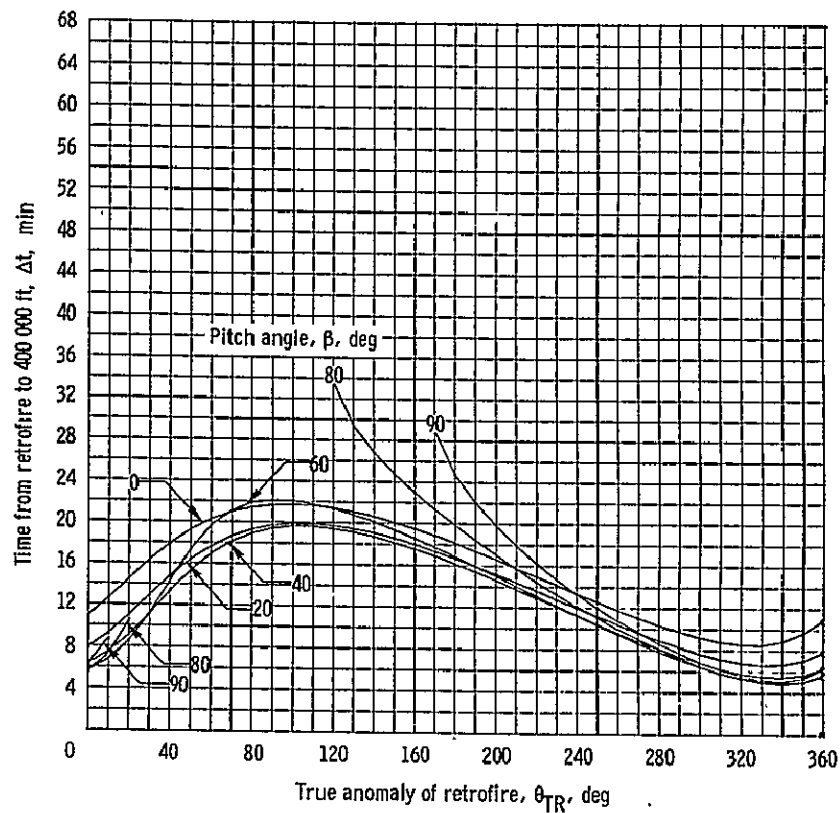
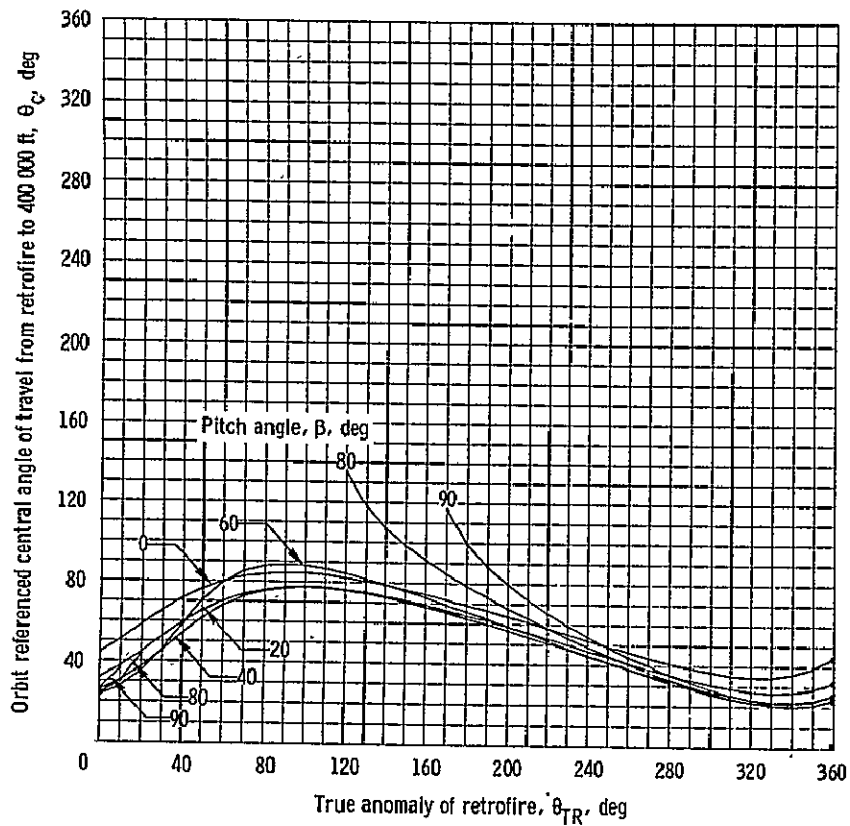
(b) Retrograde $\Delta V = 300$ fps.

Figure 16. - Continued.



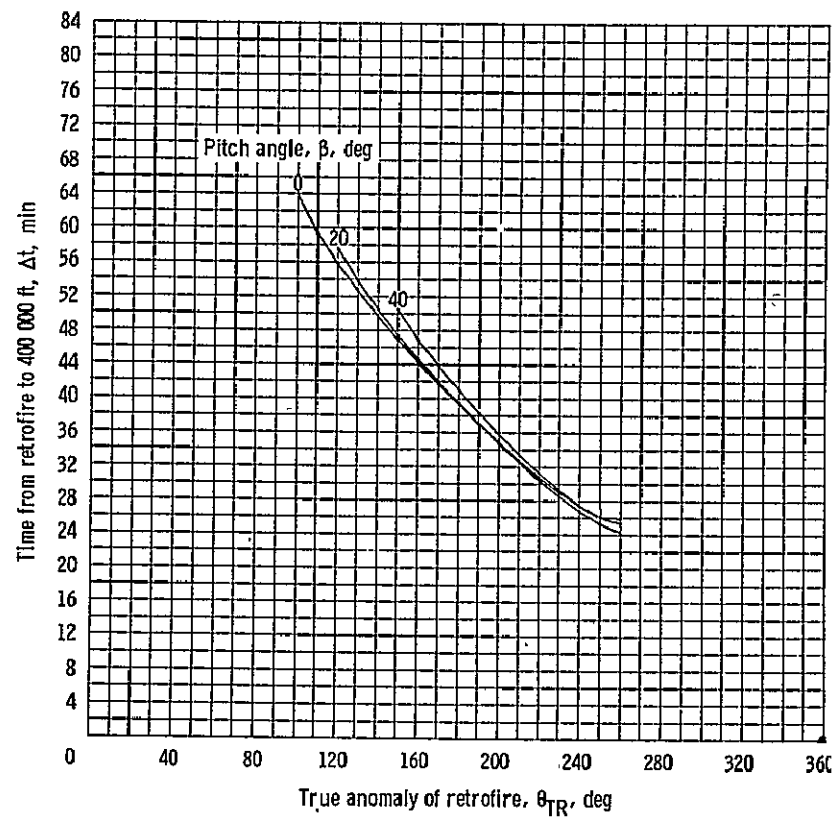
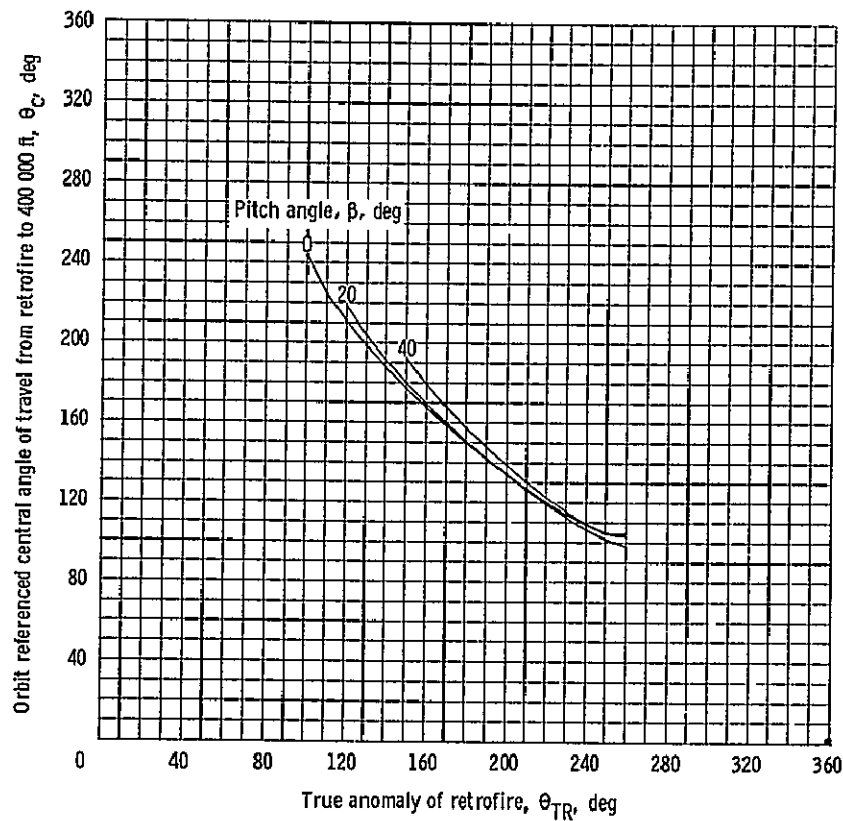
(c) Retrograde $\Delta V = 500$ fps.

Figure 16. - Continued.



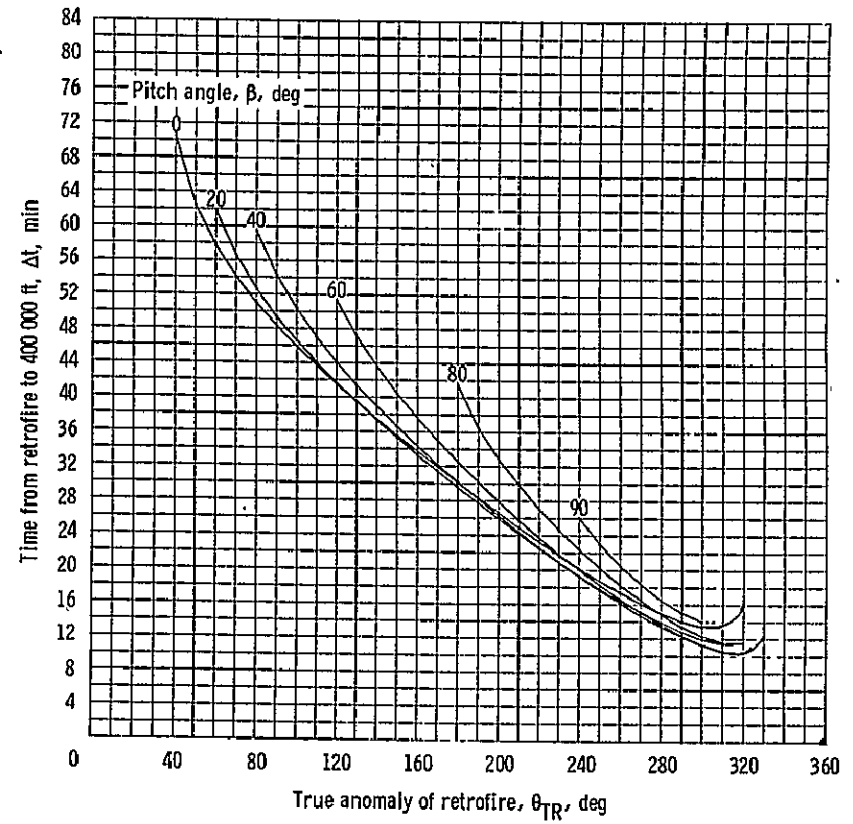
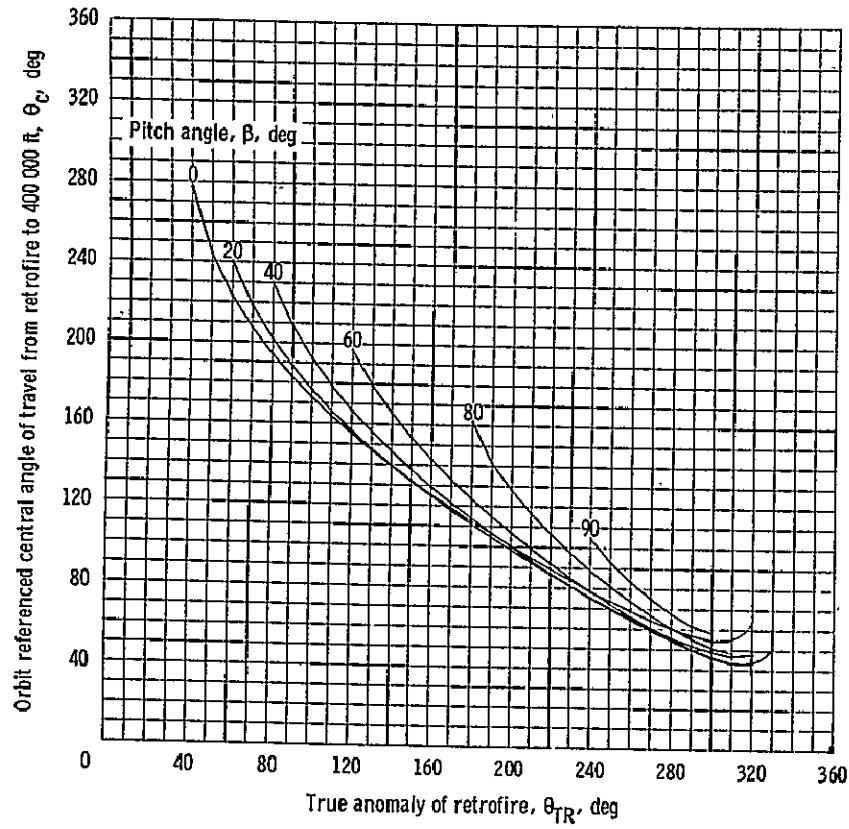
(d) Retrograde $\Delta V = 700$ fps.

Figure 16. - Concluded.



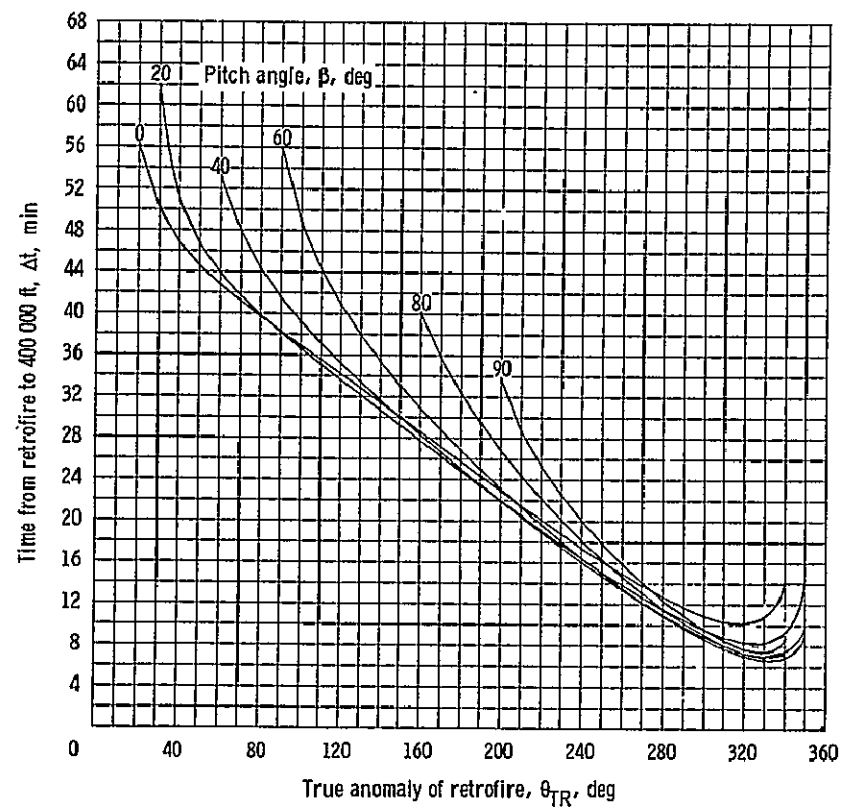
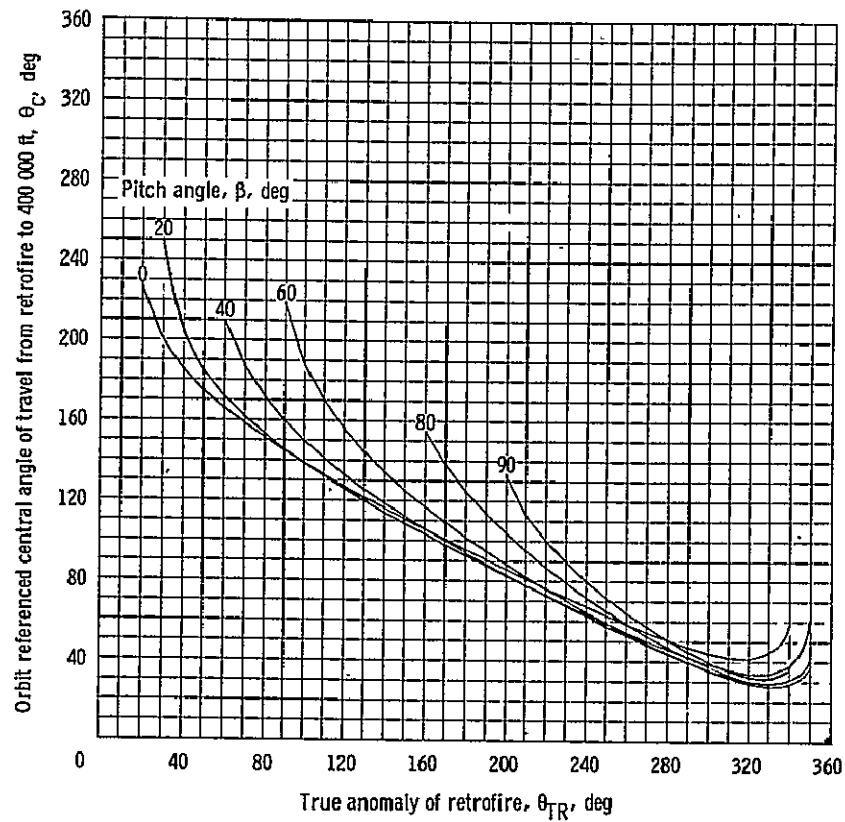
(a) Retrograde $\Delta V = 100$ fps.

Figure 17.- Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 400$ nautical miles and $h_p = 100$ nautical miles.



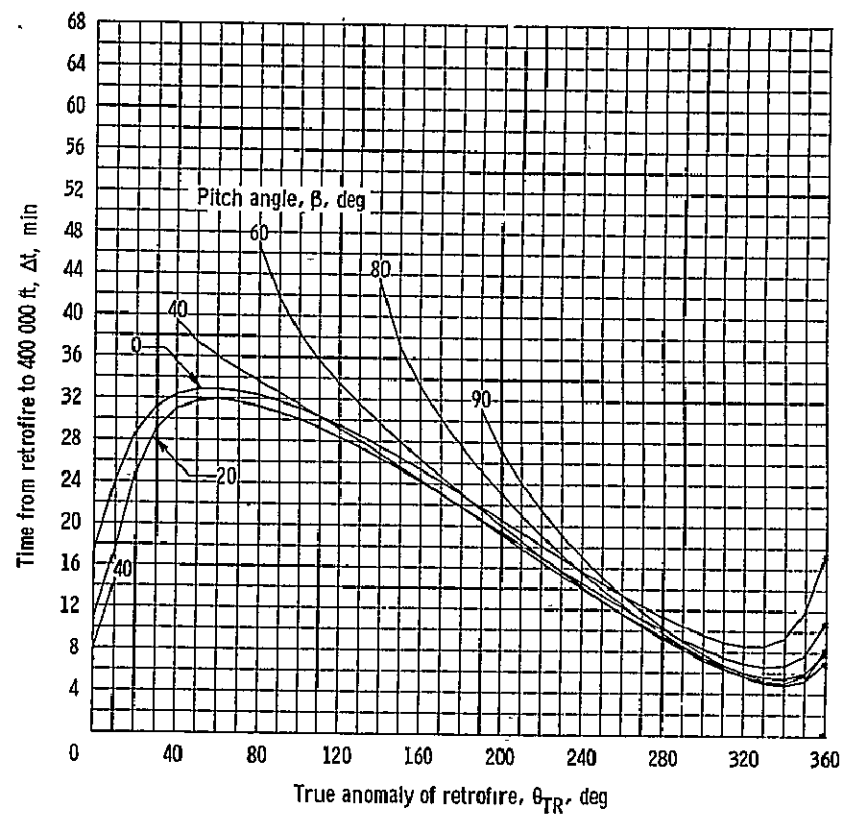
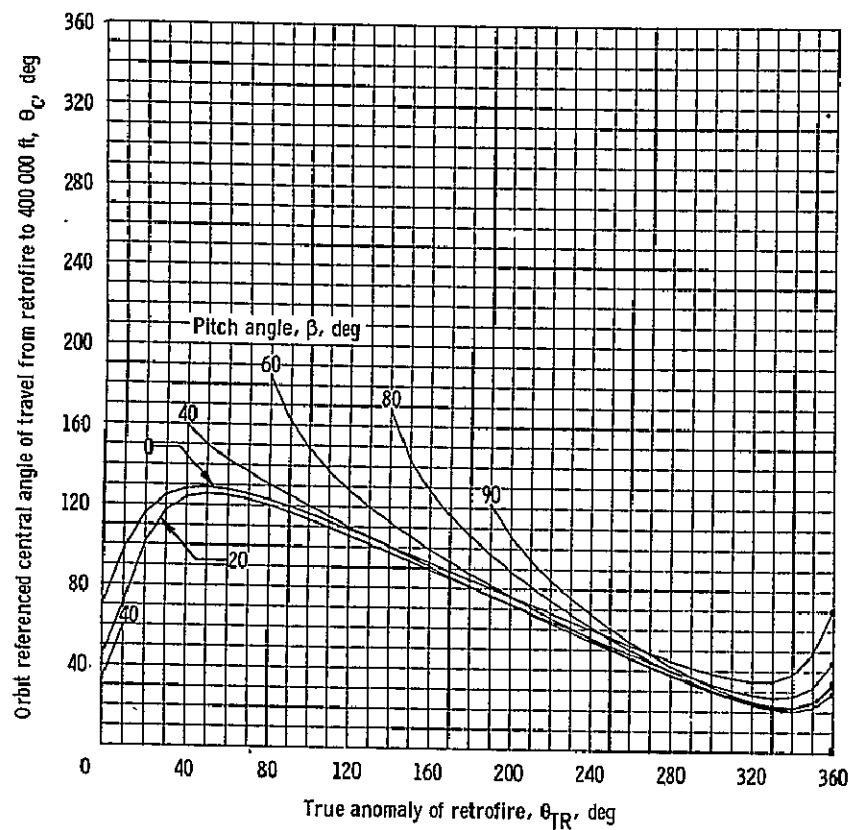
(b) Retrograde $\Delta V = 300$ fps.

Figure 17. - Continued.



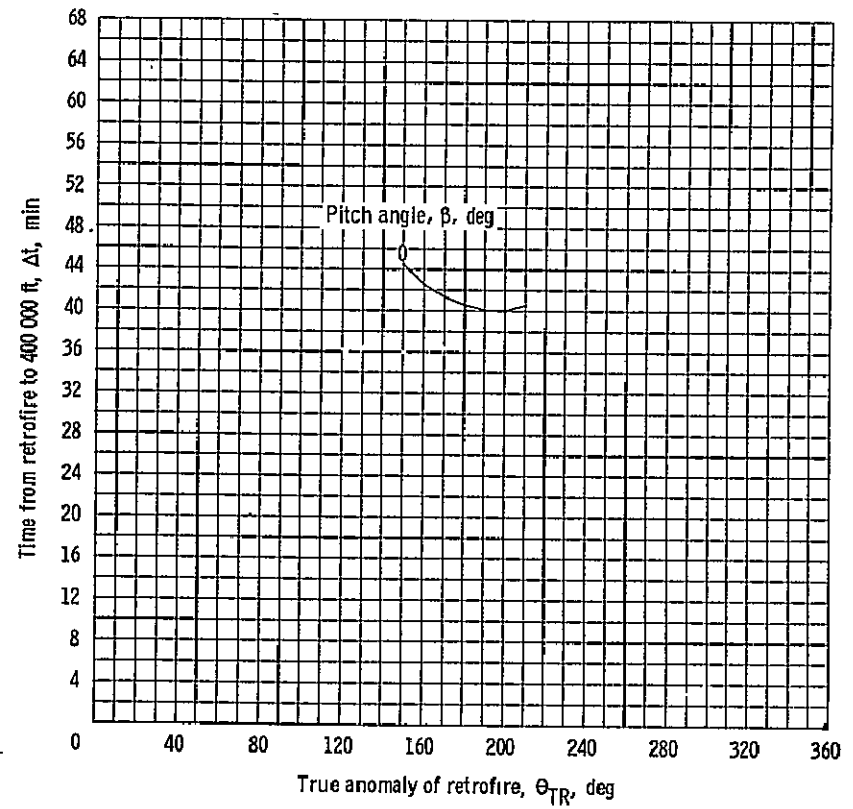
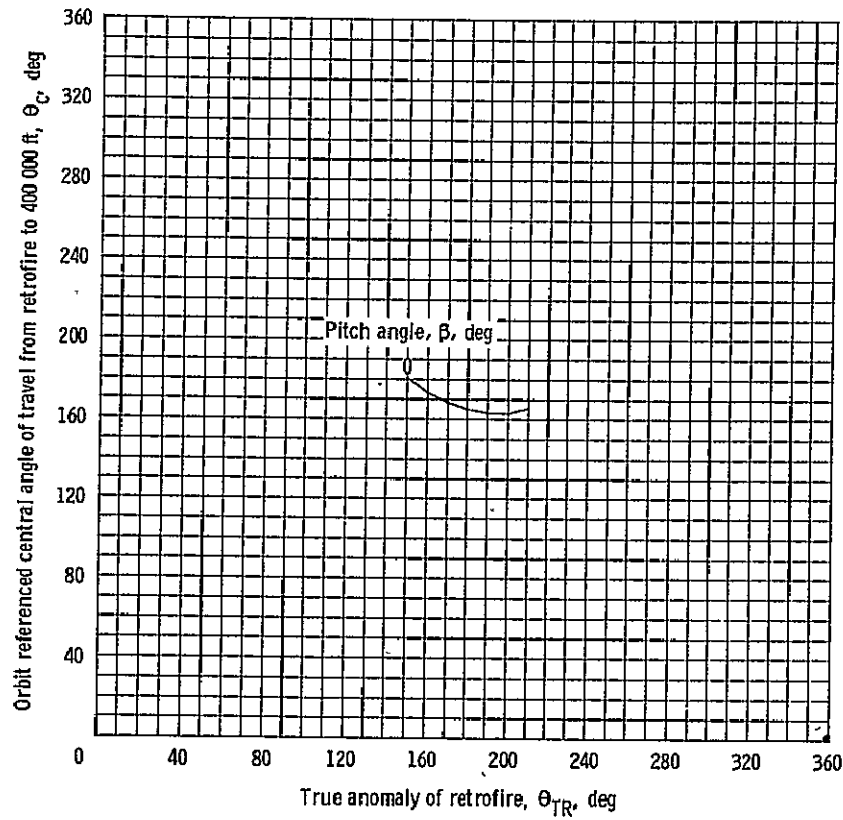
(c) Retrograde $\Delta V = 500$ fps.

Figure 17. - Continued.



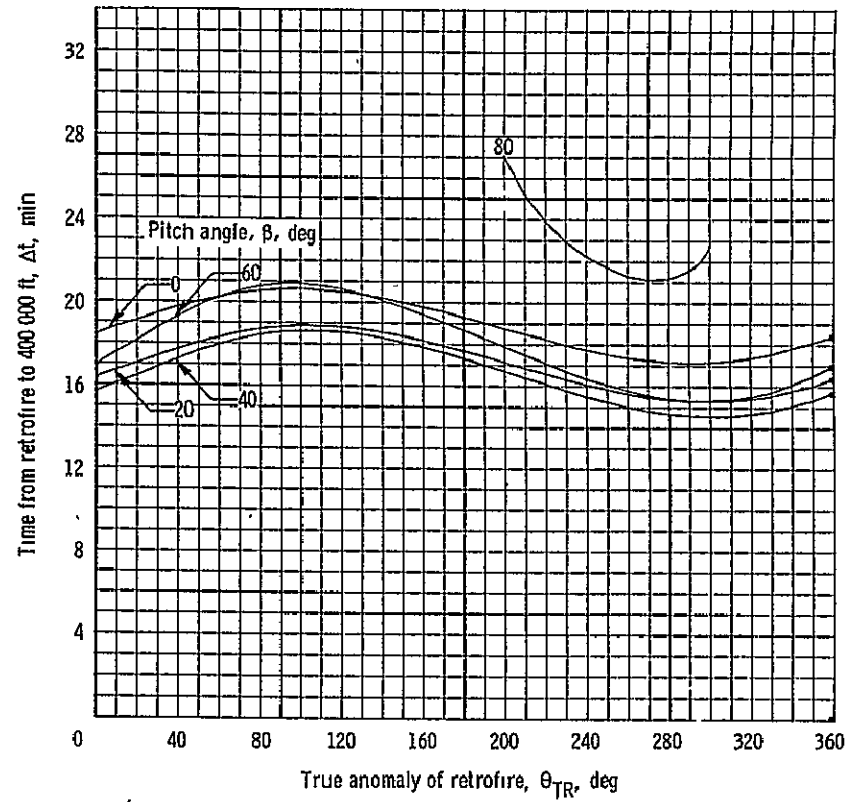
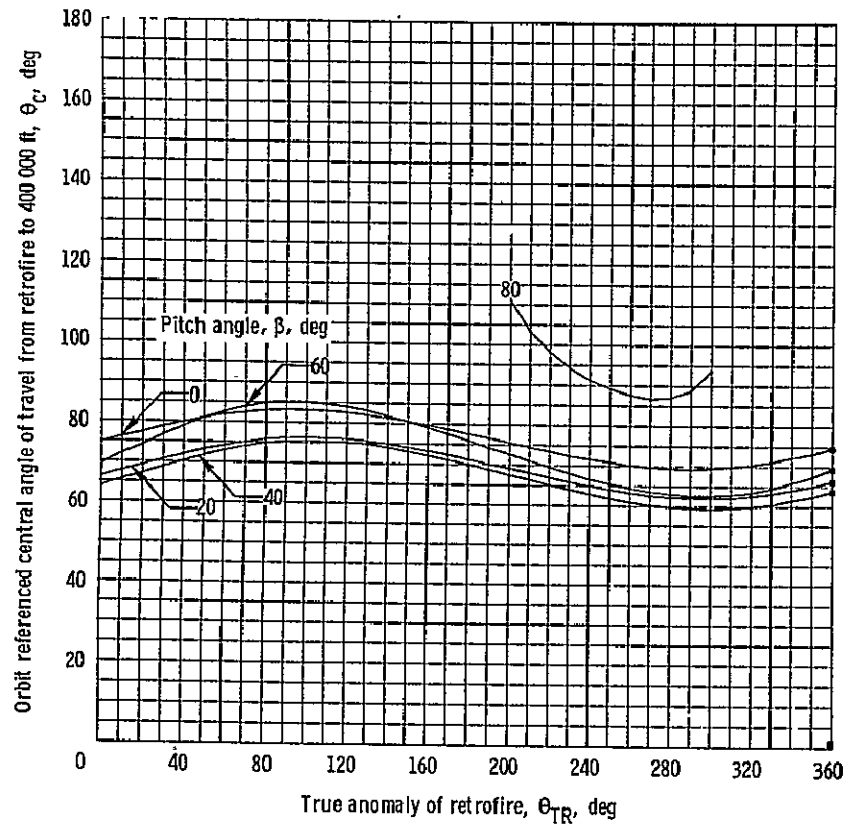
(d) Retrograde $\Delta V = 700$ fps.

Figure 17. - Concluded.



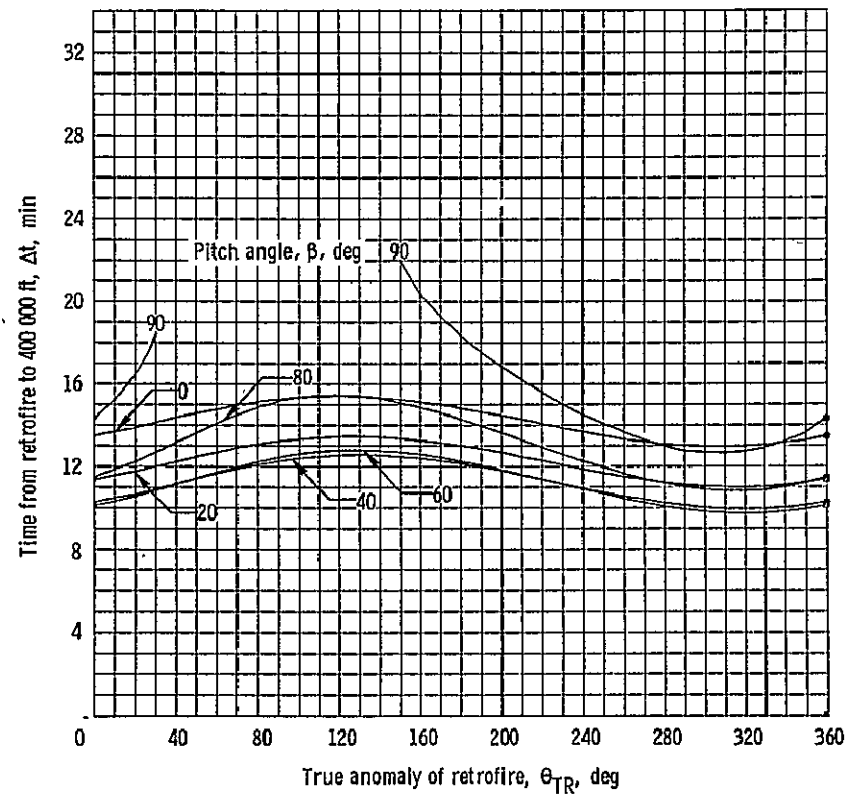
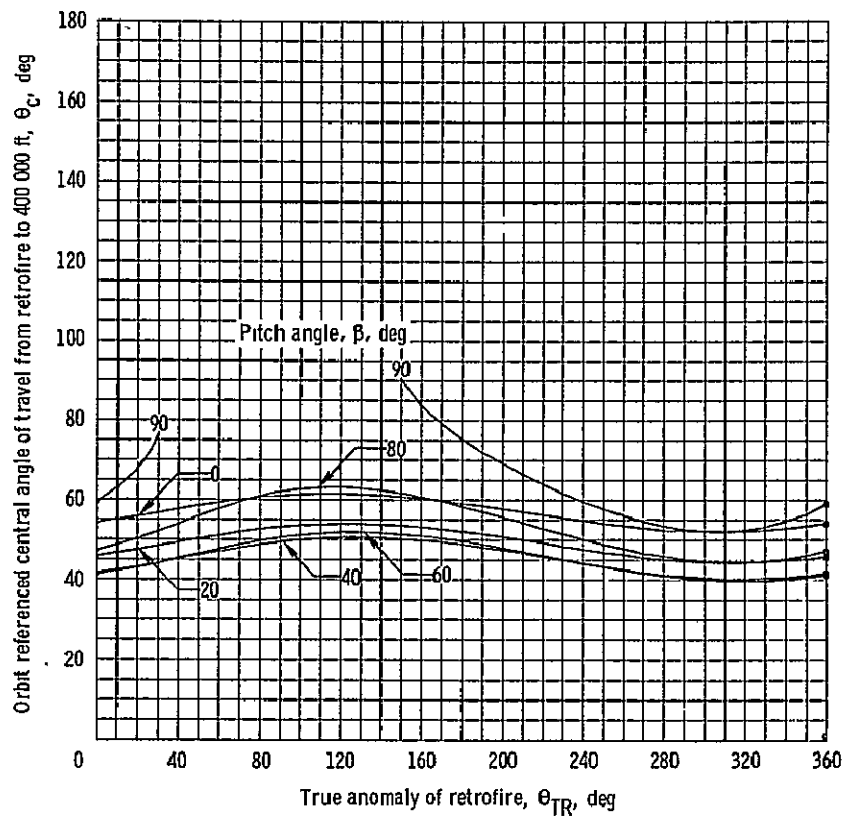
(a) Retrograde $\Delta V = 100$ fps.

Figure 18.- Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 140$ nautical miles and $h_p = 120$ nautical miles.



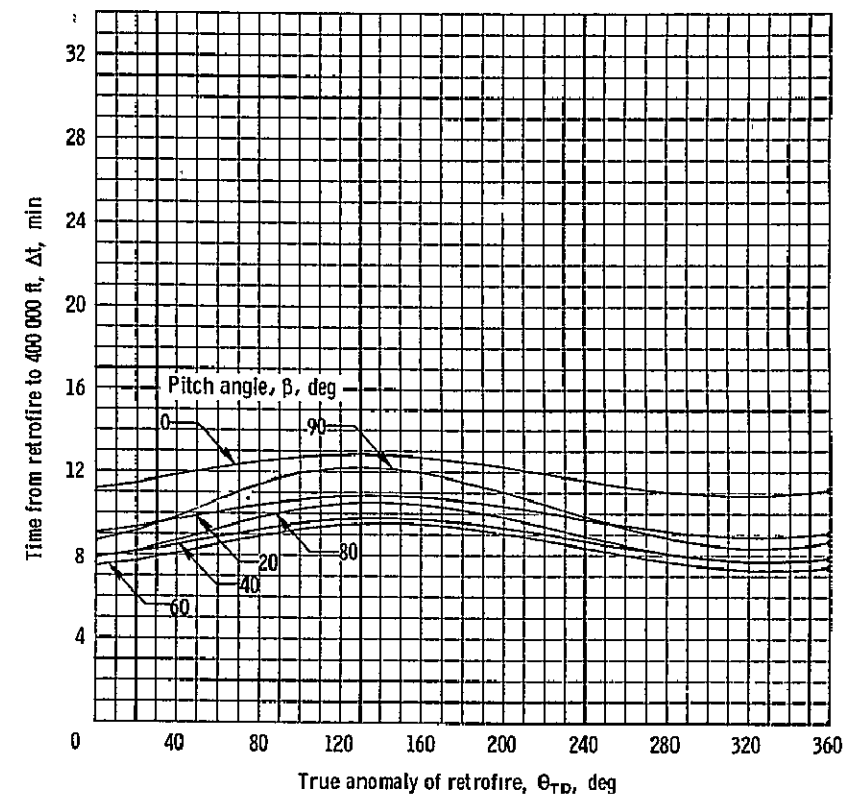
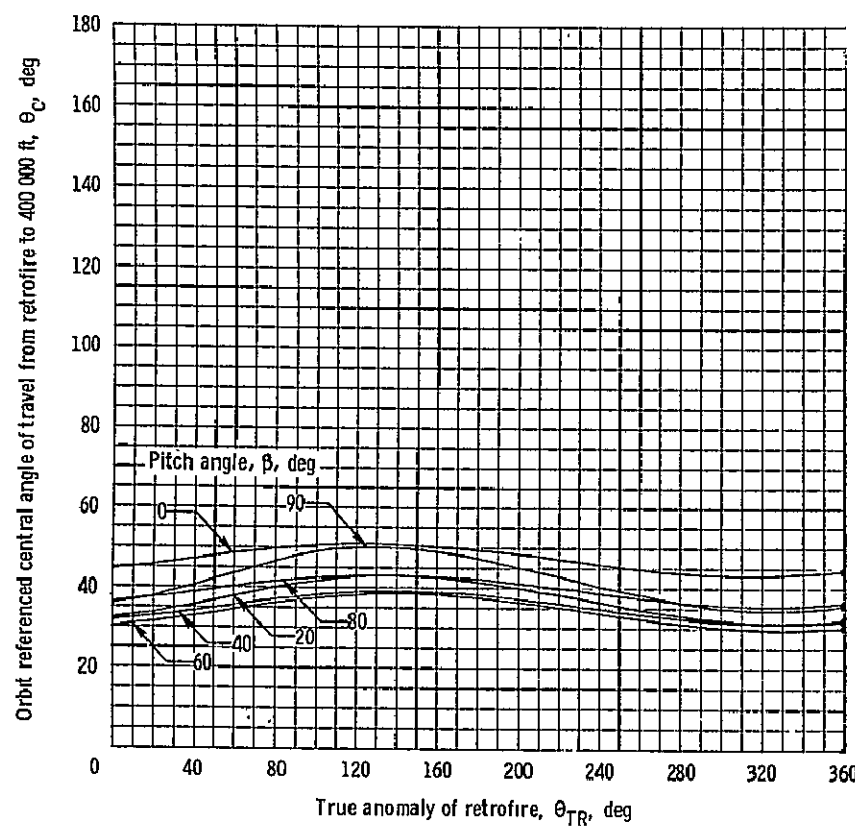
(b) Retrograde $\Delta V = 300$ fps.

Figure 18. - Continued.



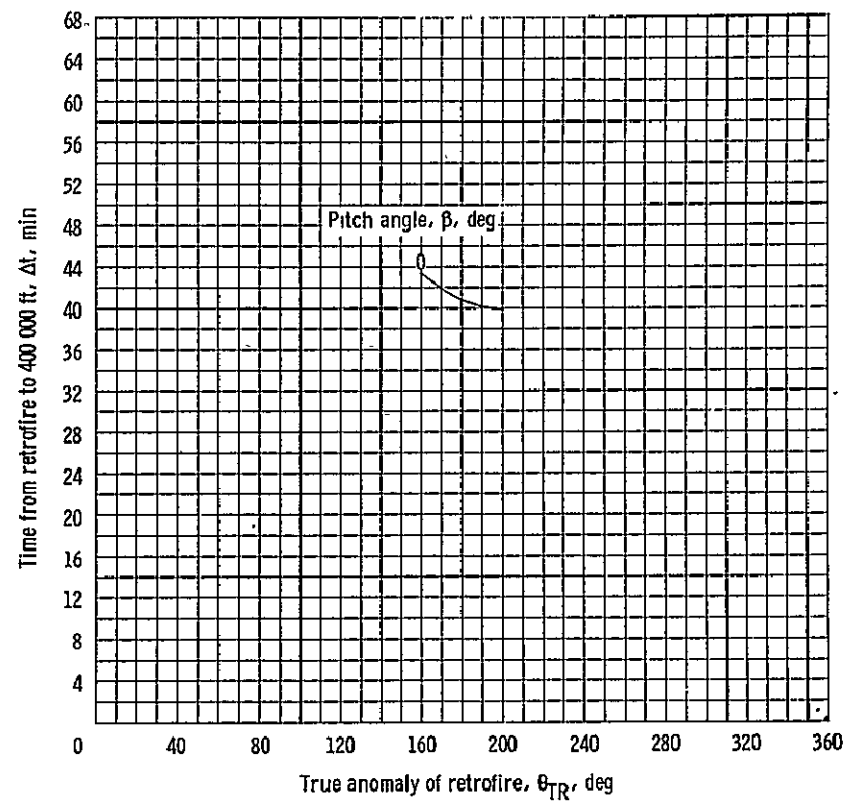
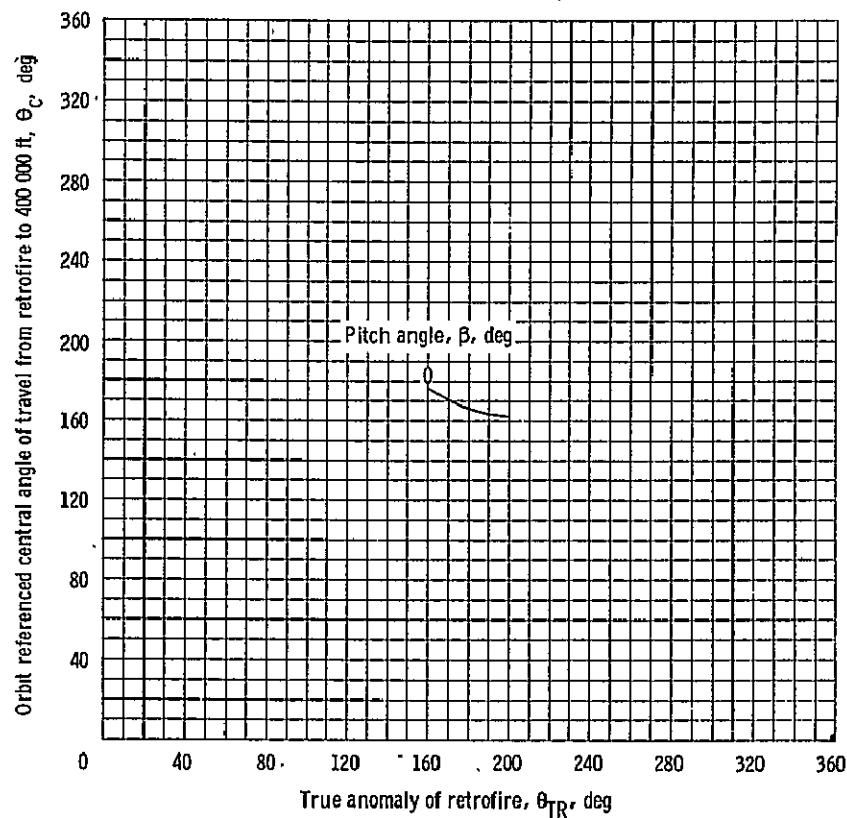
(c) Retrograde $\Delta V = 500$ fps.

Figure 18. - Continued.



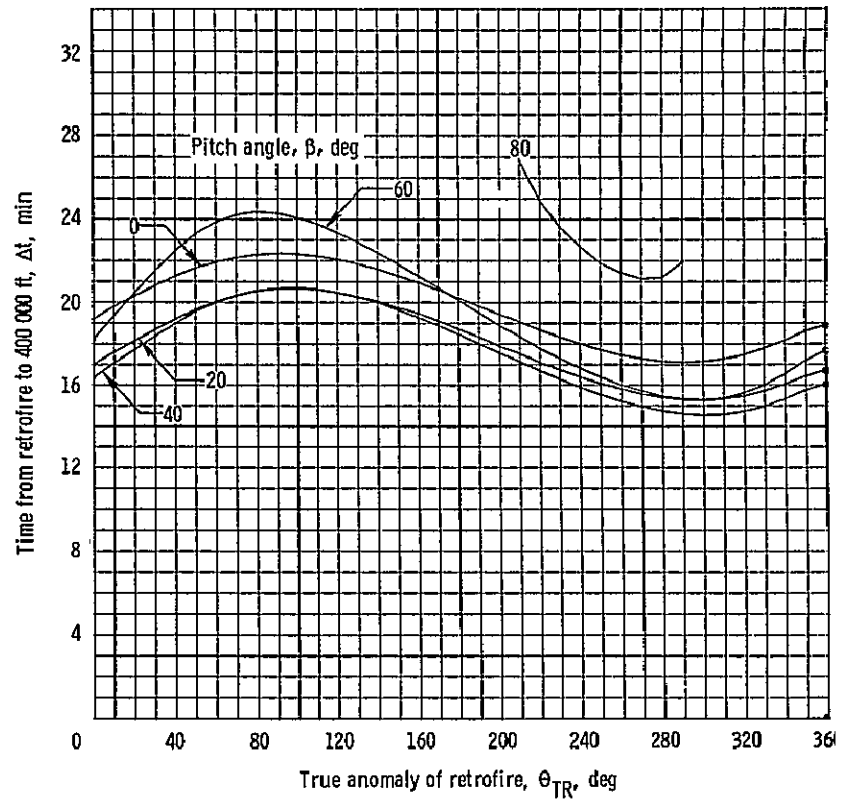
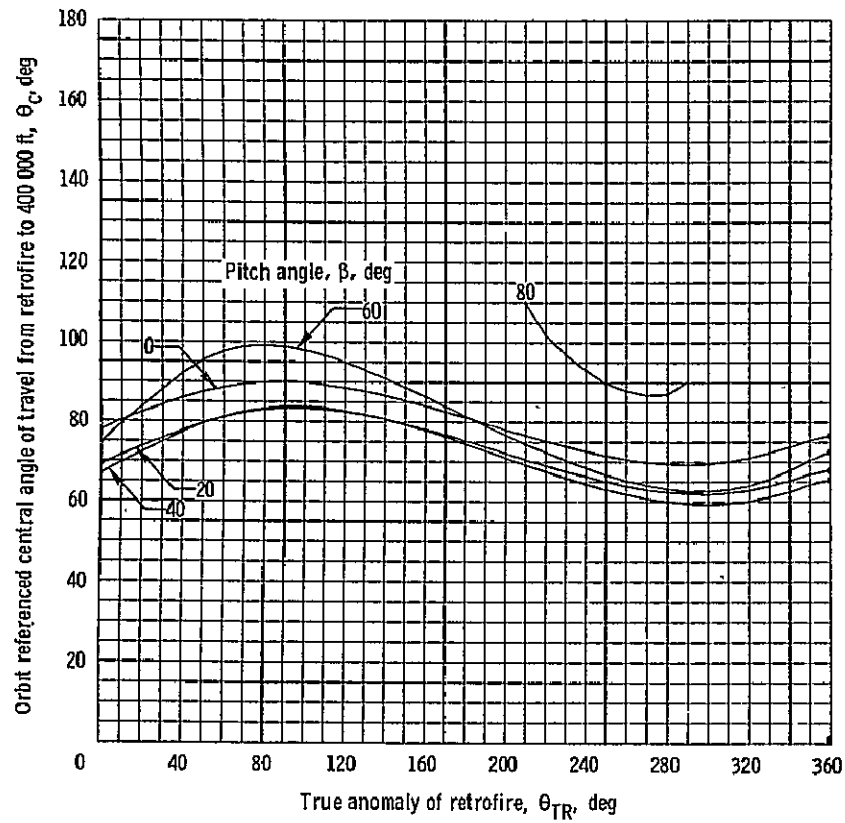
(d) Retrograde $\Delta V = 700$ fps.

Figure 18. - Concluded.



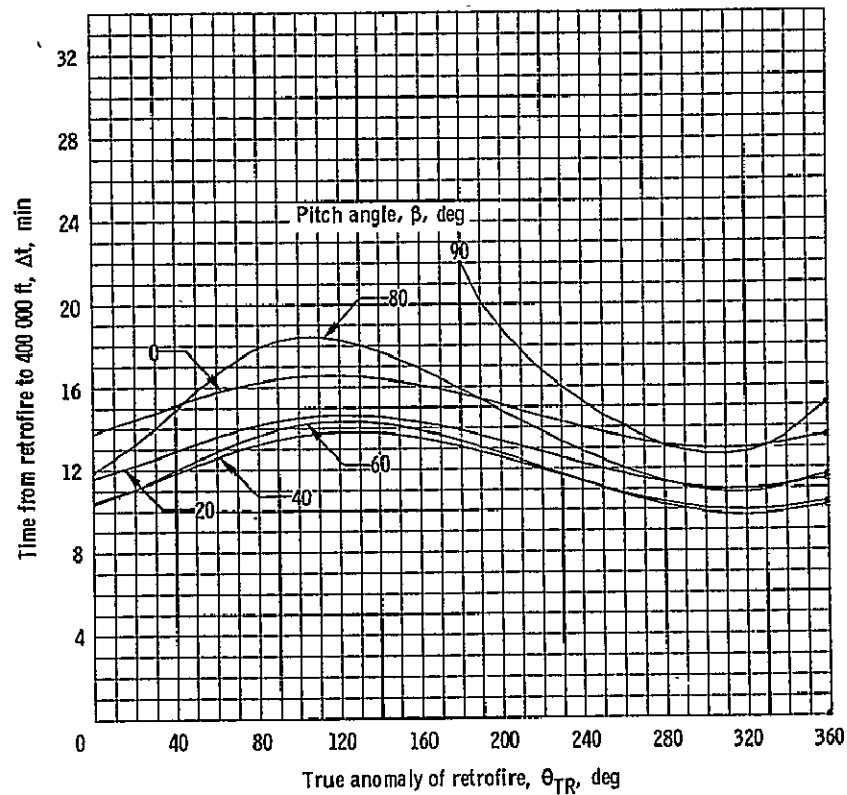
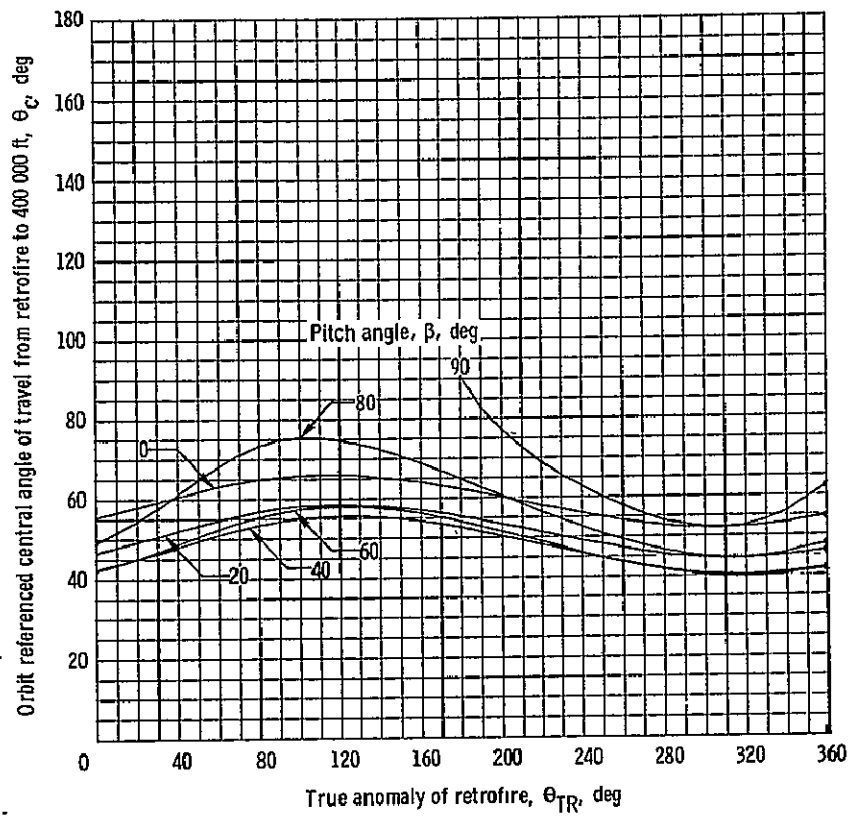
(a) Retrograde $\Delta V = 100$ fps.

Figure 19. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 150$ nautical miles and $h_p = 120$ nautical miles.



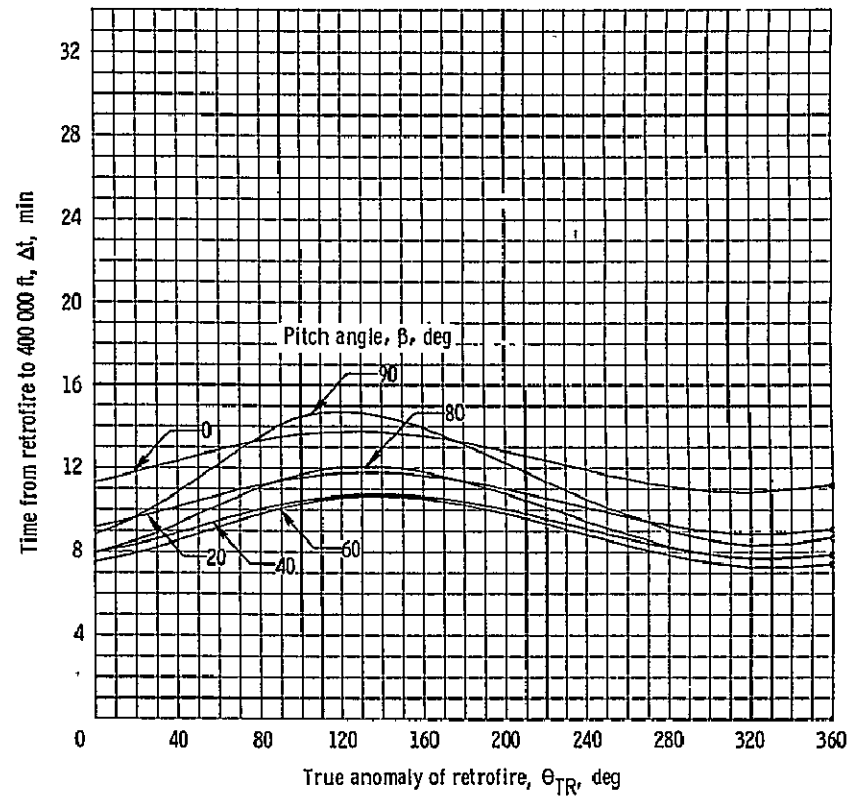
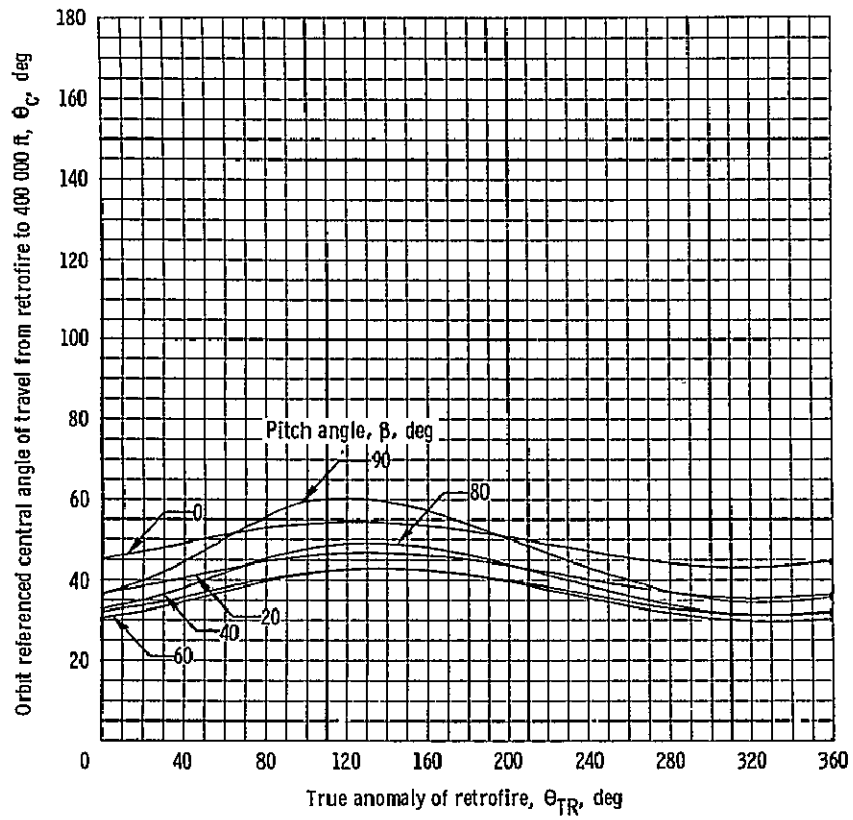
(b) Retrograde $\Delta V = 300$ fps.

Figure 19. - Continued.



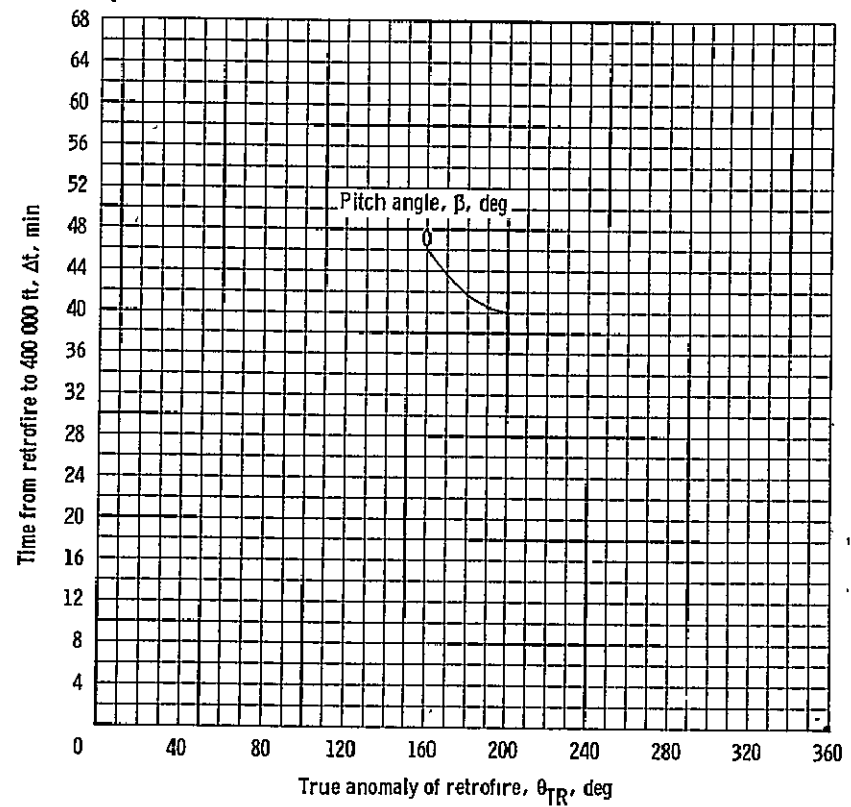
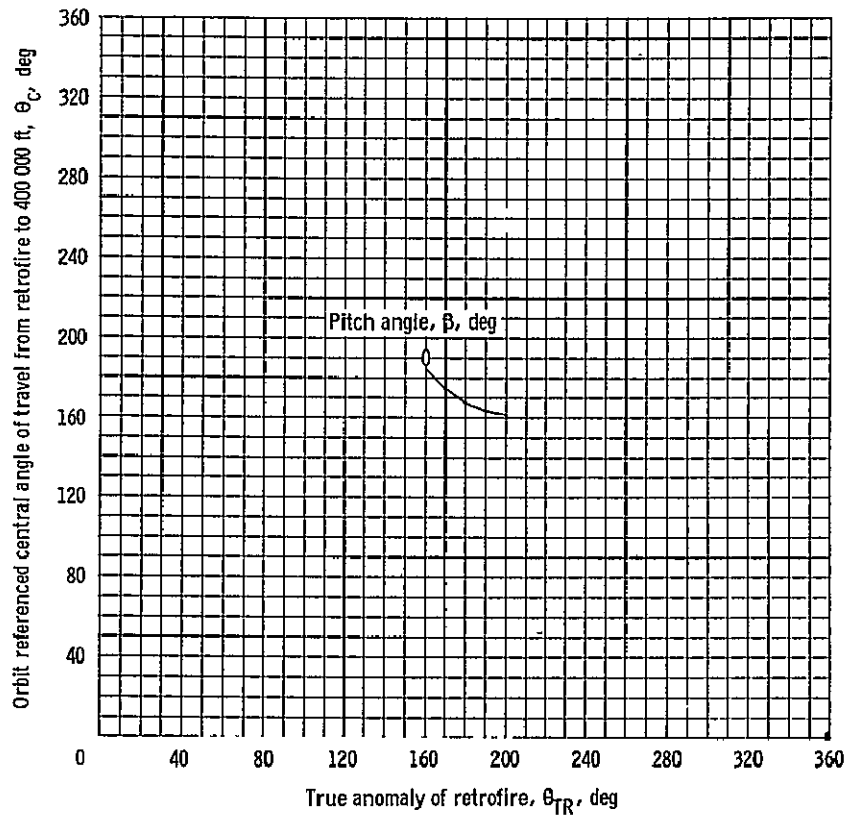
(c) Retrograde $\Delta V = 500$ fps.

Figure 19. - Continued.



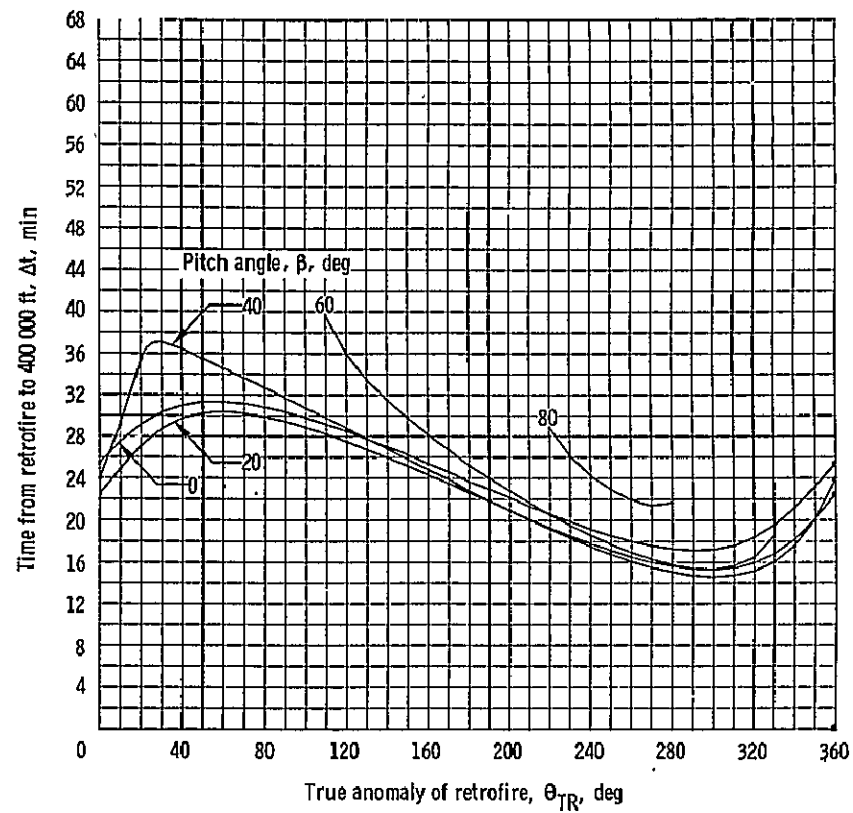
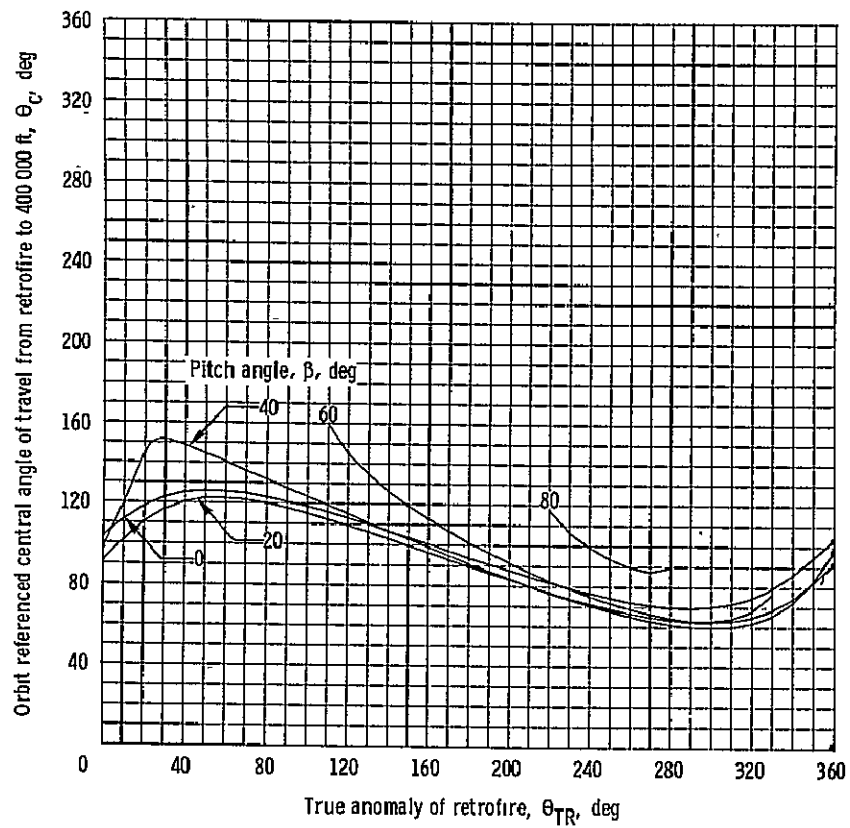
(d) Retrograde $\Delta V = 700$ fps.

Figure 19.- Concluded.



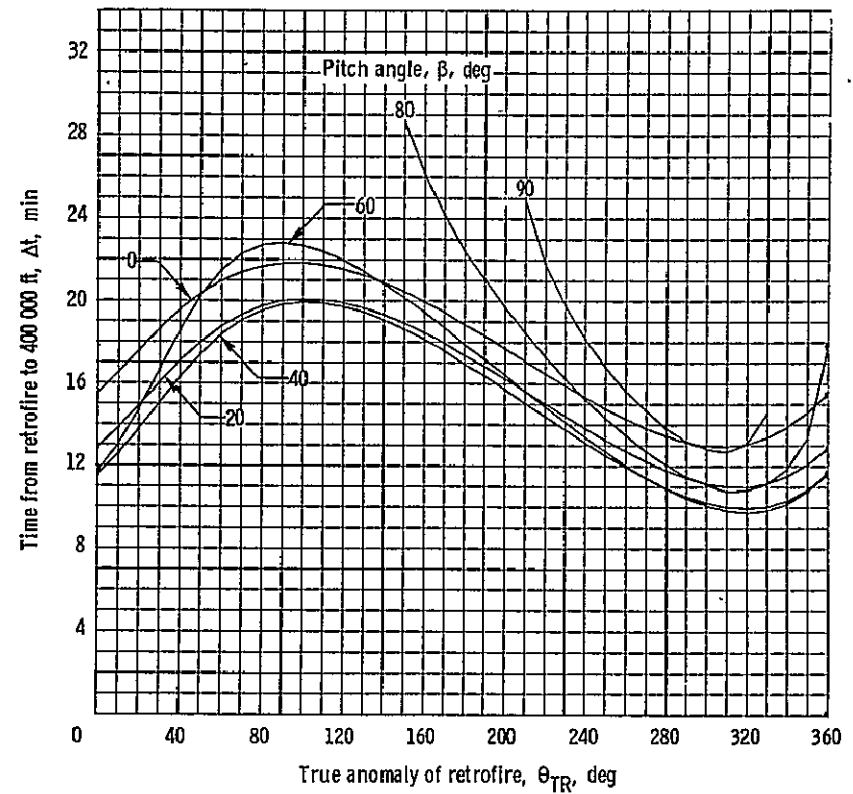
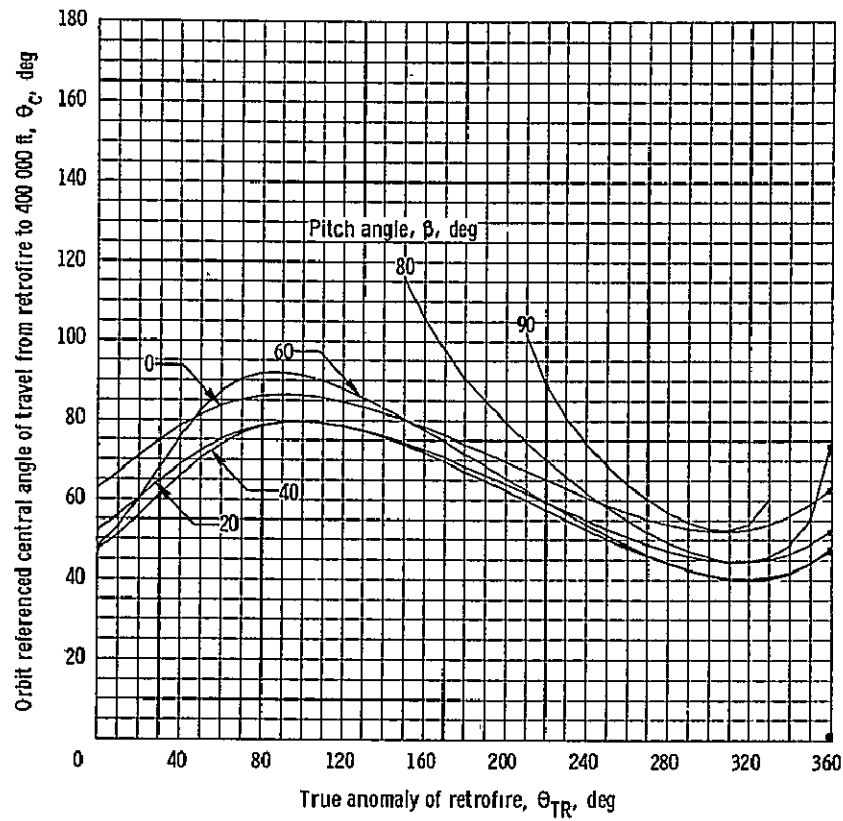
(a) Retrograde $\Delta V = 100$ fps.

Figure 20.- Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 200$ nautical miles and $h_p = 120$ nautical miles.



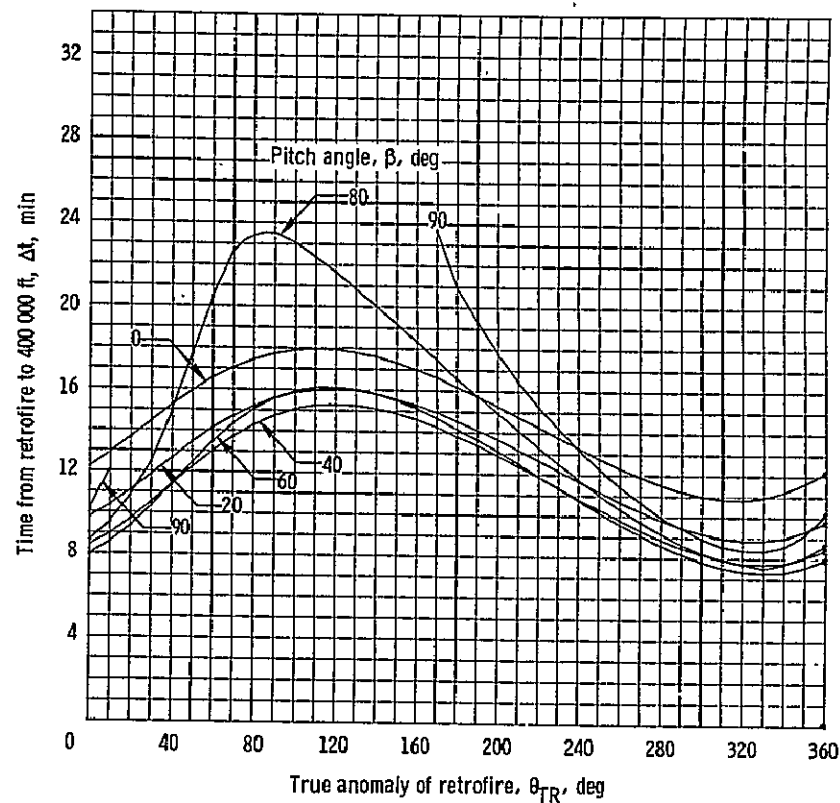
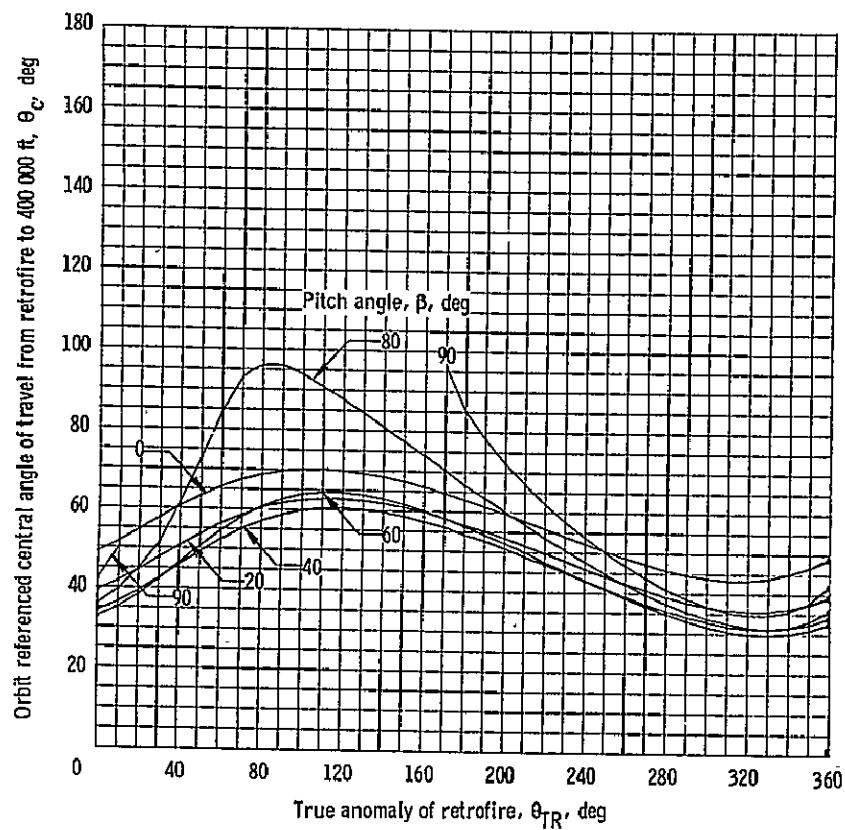
(b) Retrograde $\Delta V = 300$ fps.

Figure 20. - Continued.



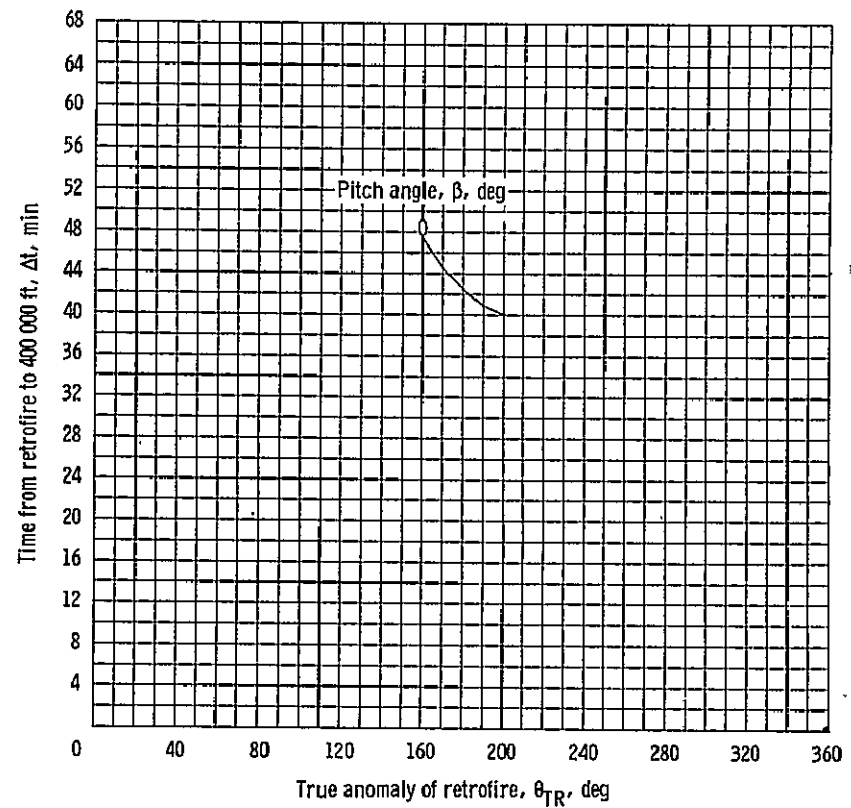
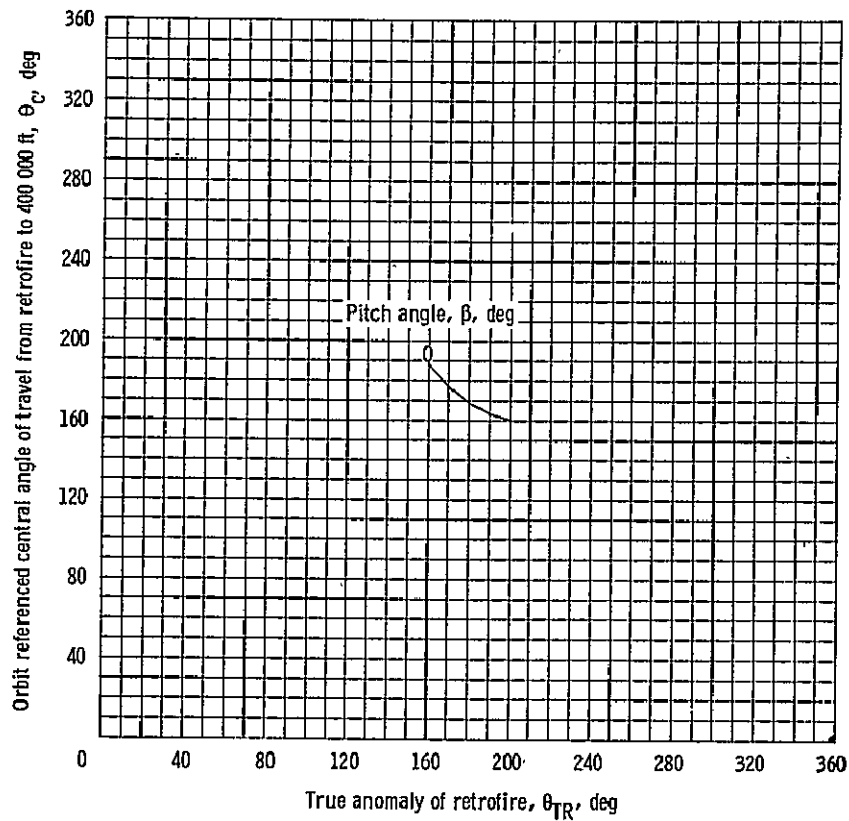
(c) Retrograde $\Delta V = 500$ fps.

Figure 20. - Continued.



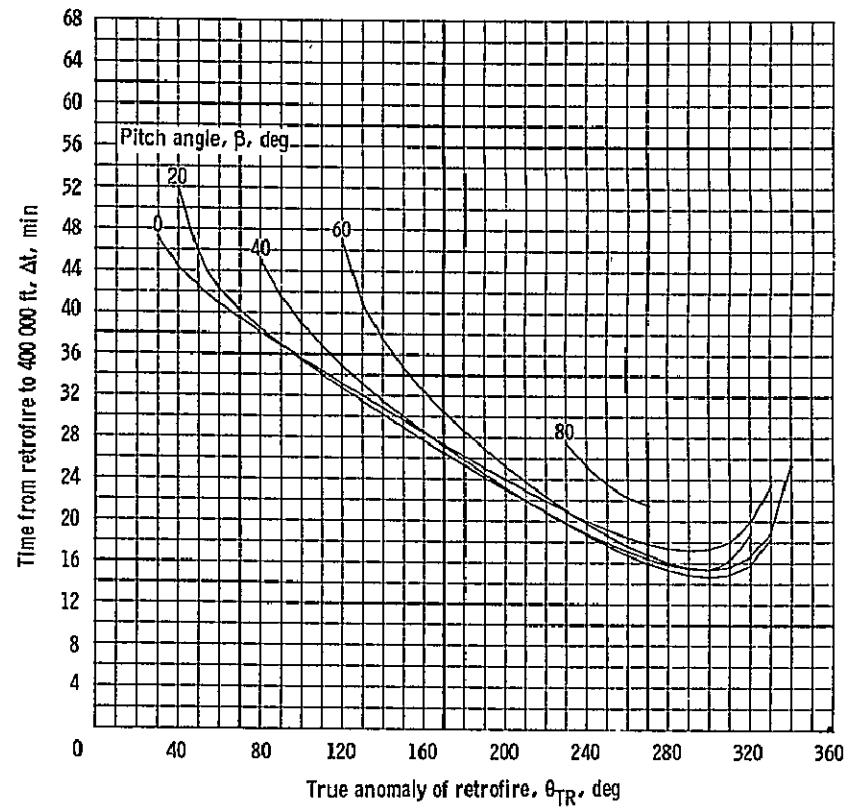
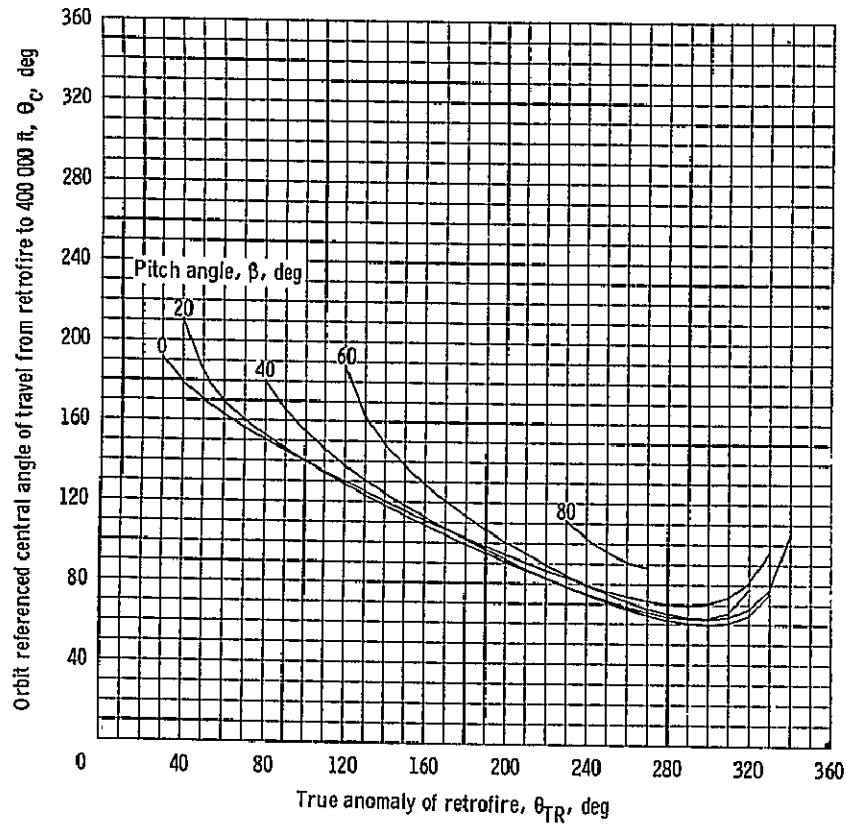
(d) Retrograde $\Delta V = 700$ fps.

Figure 20. - Concluded.



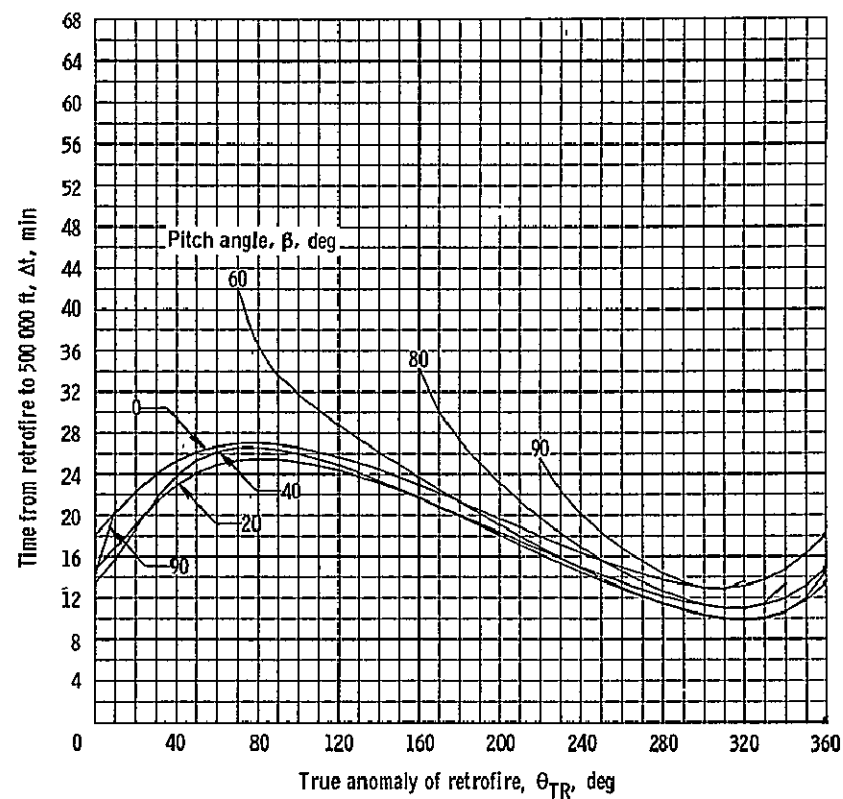
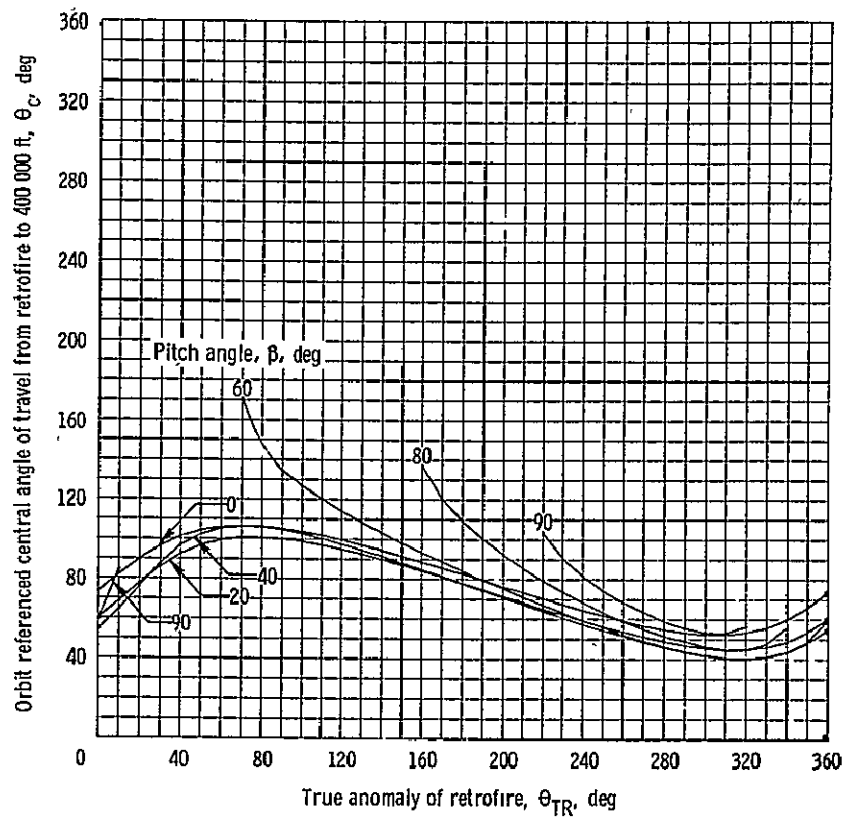
(a) Retrograde $\Delta V = 100$ fps.

Figure 21. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 250$ nautical miles and $h_p = 120$ nautical miles.



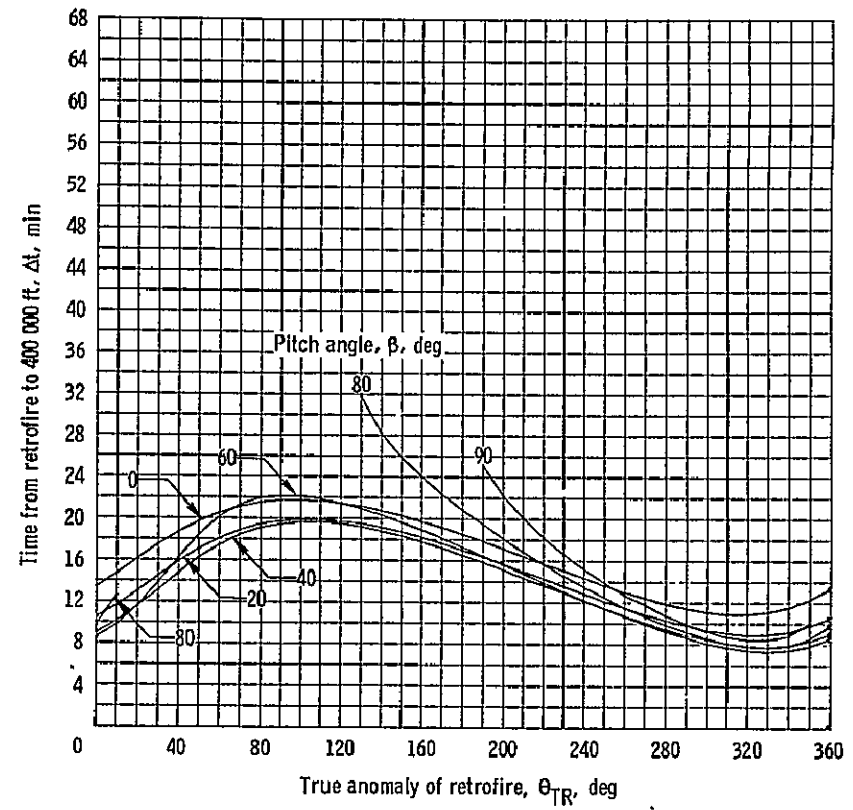
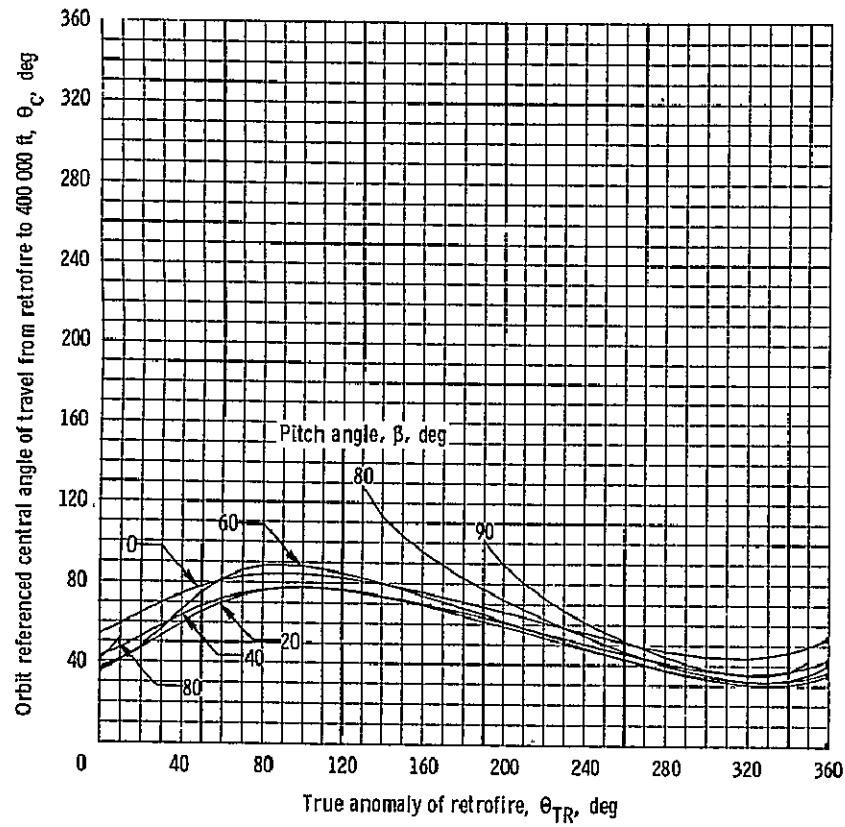
(b) Retrograde $\Delta V = 300$ fps.

Figure 21. - Continued.



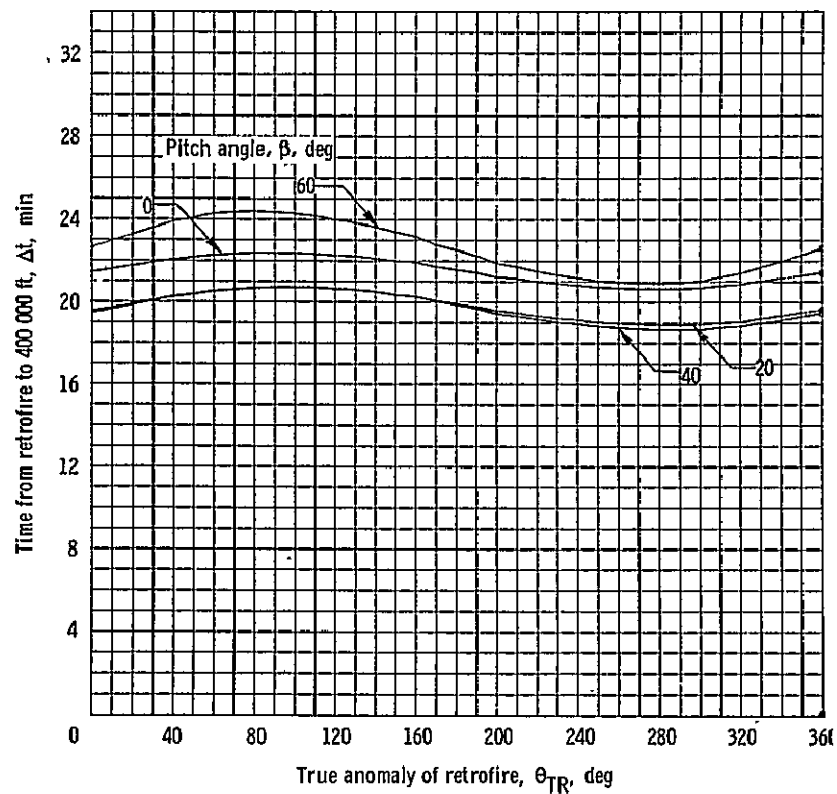
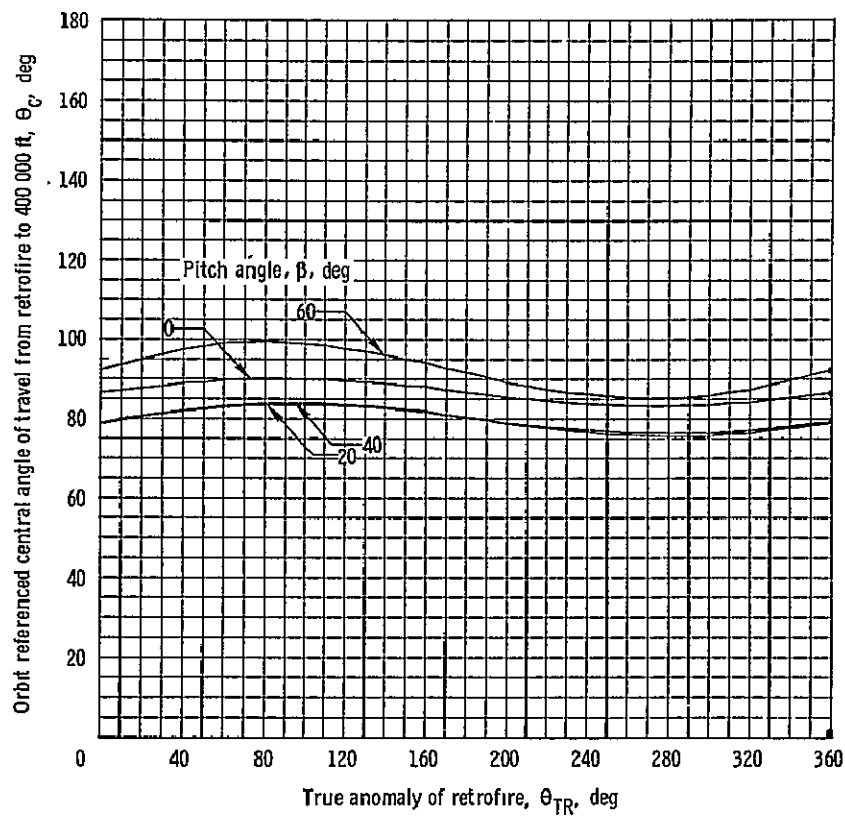
(c) Retrograde $\Delta V = 500$ fps.

Figure 21. - Continued.



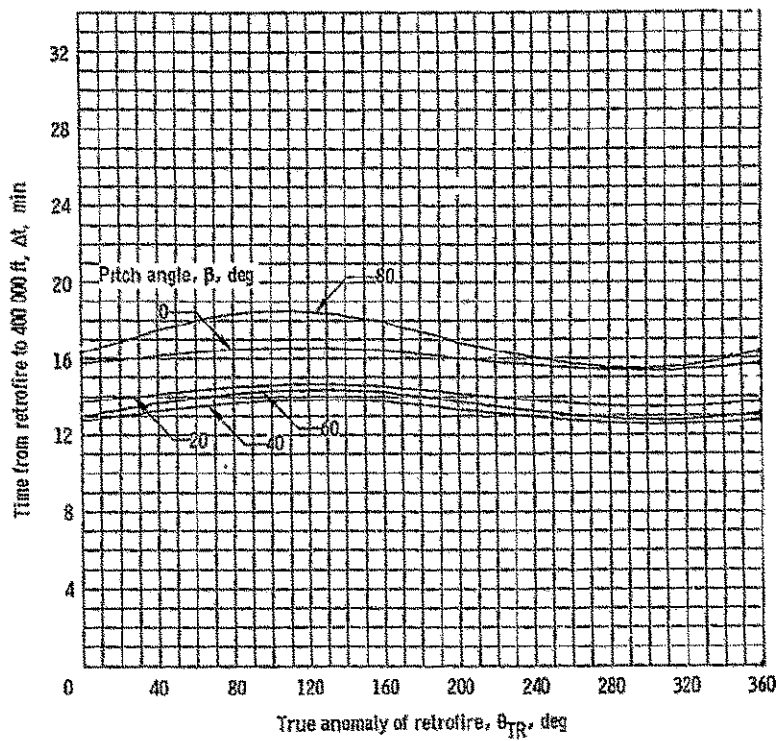
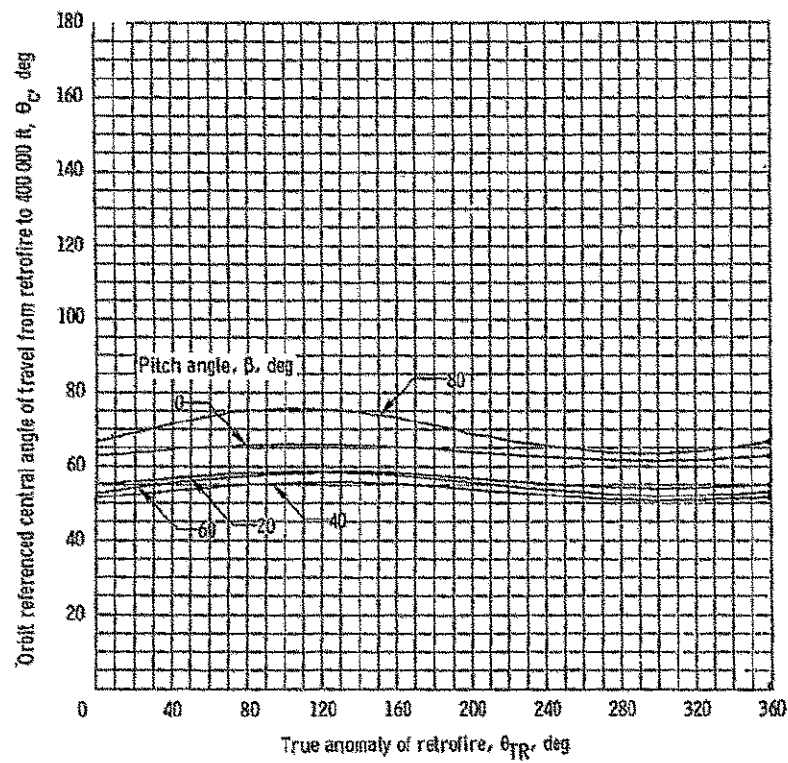
(d) Retrograde $\Delta V = 700$ fps.

Figure 21. - Concluded.



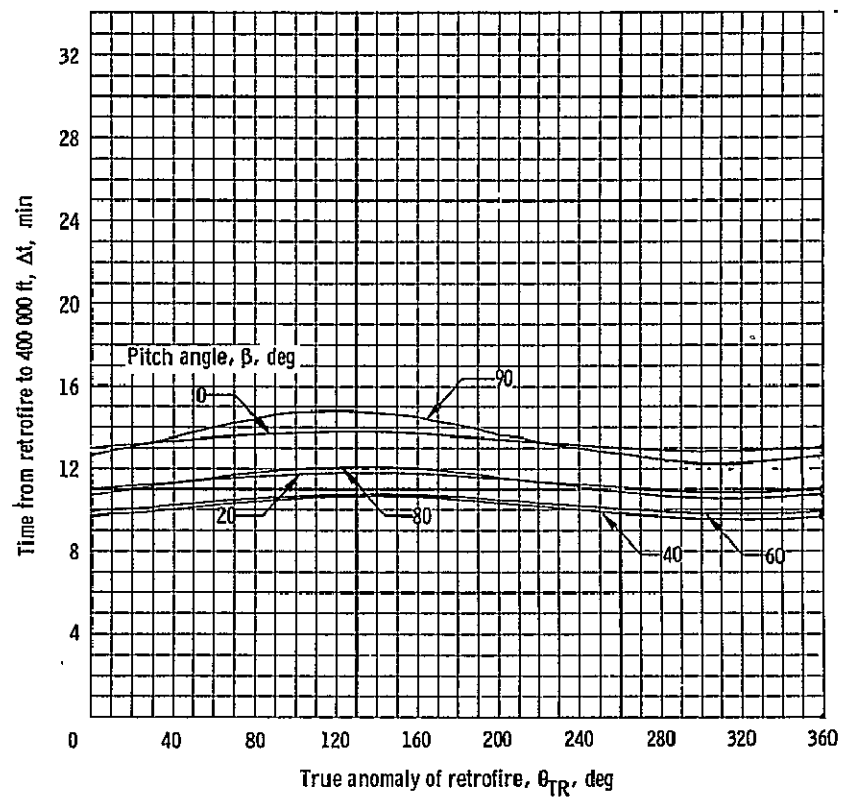
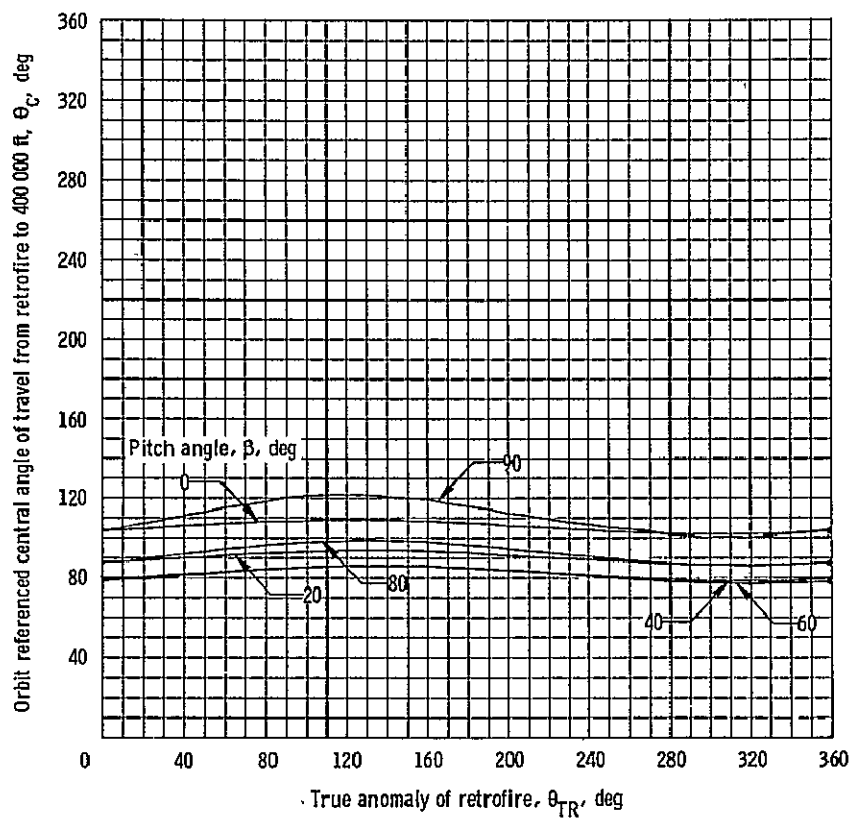
(a) Retrograde $\Delta V = 300$ fps.

Figure 22. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 150$ nautical miles and $h_p = 140$ nautical miles.



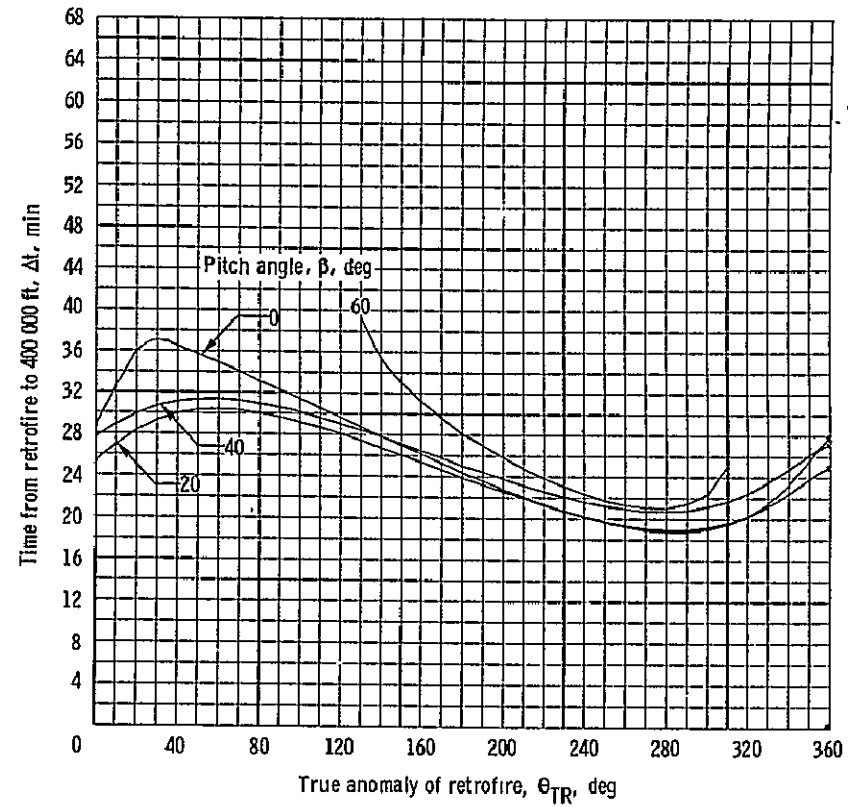
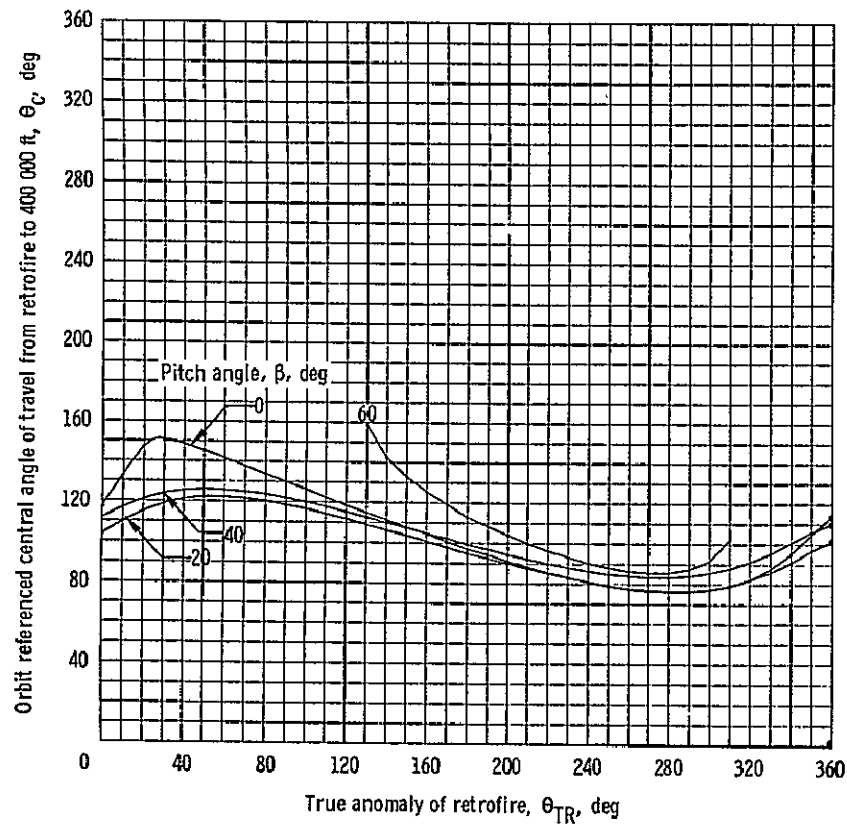
(b) Retrograde $\Delta V = 500$ fps.

Figure 22. - Continued.



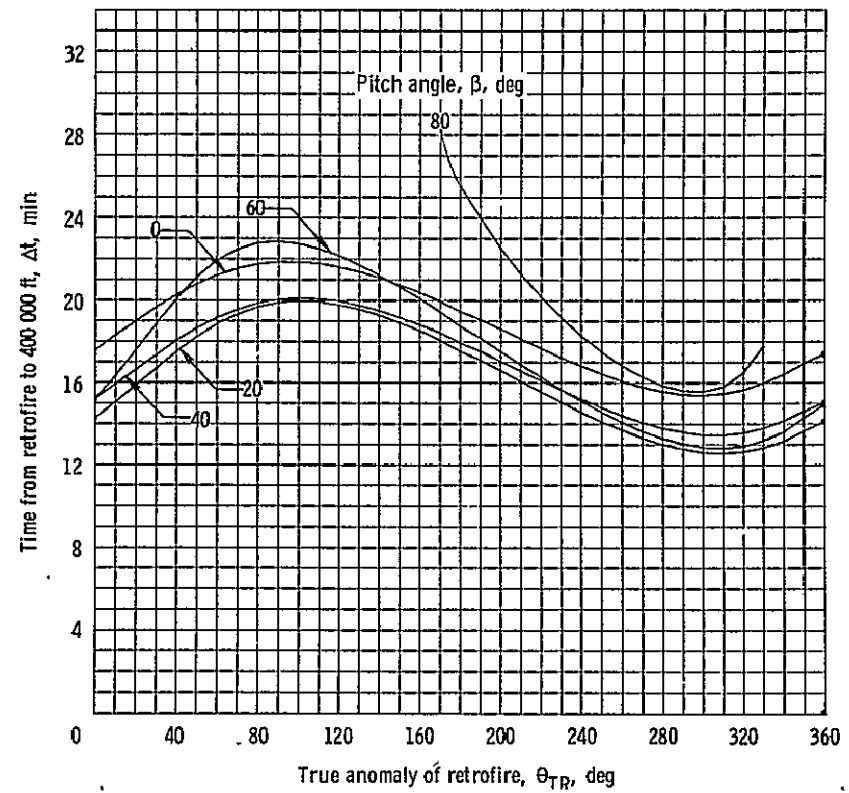
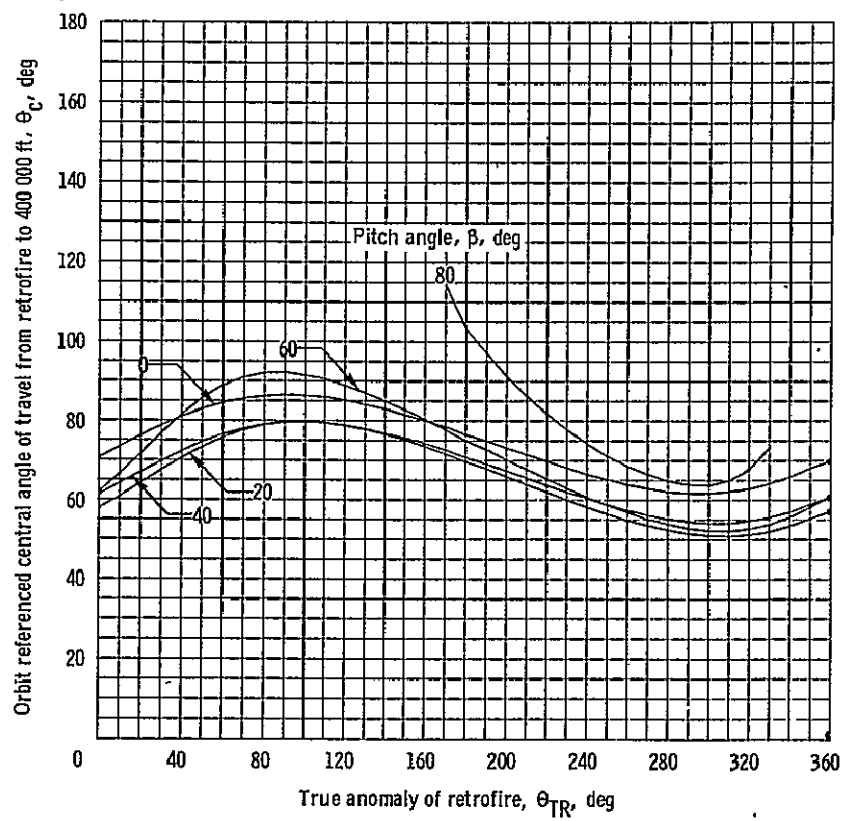
(c) Retrograde $\Delta V = 700$ fps.

Figure 22. - Concluded.



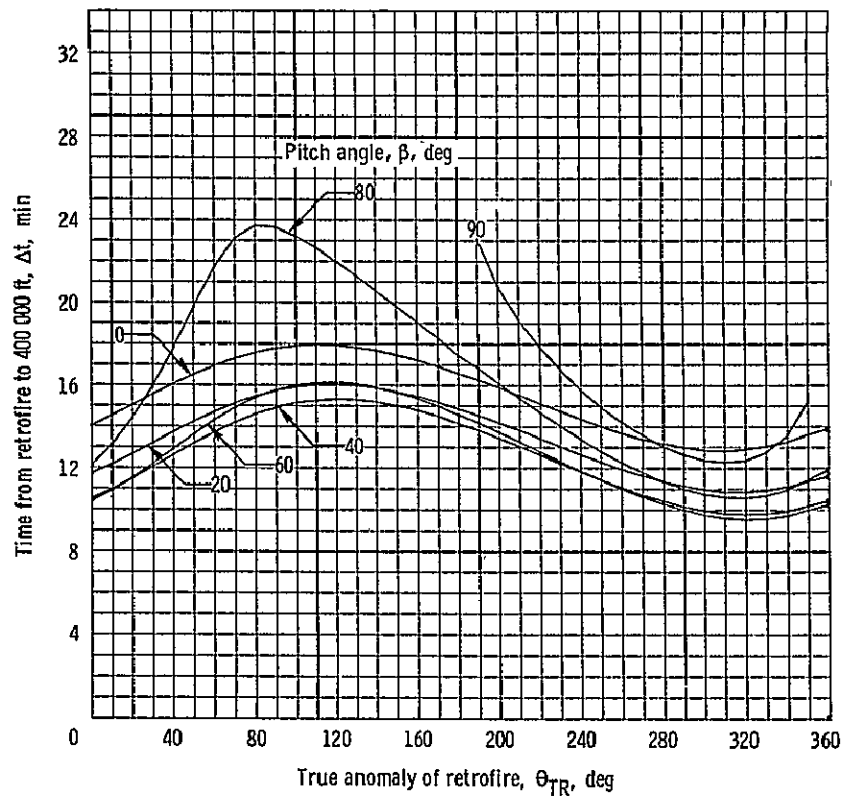
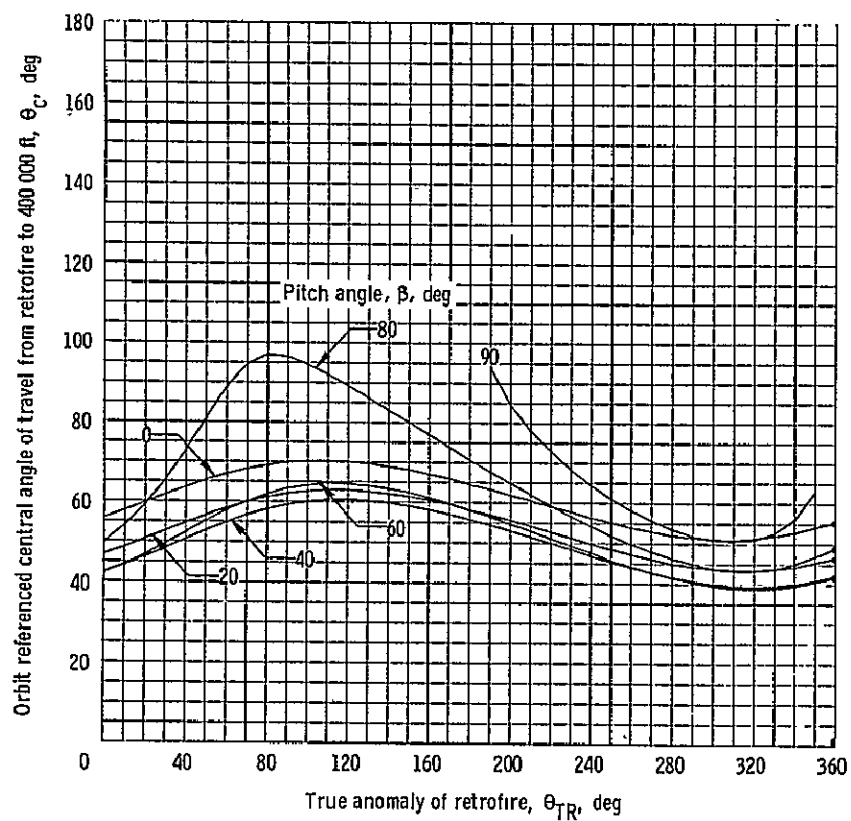
(a) Retrograde $\Delta V = 300$ fps.

Figure 23.- Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 200$ nautical miles and $h_p = 140$ nautical miles.



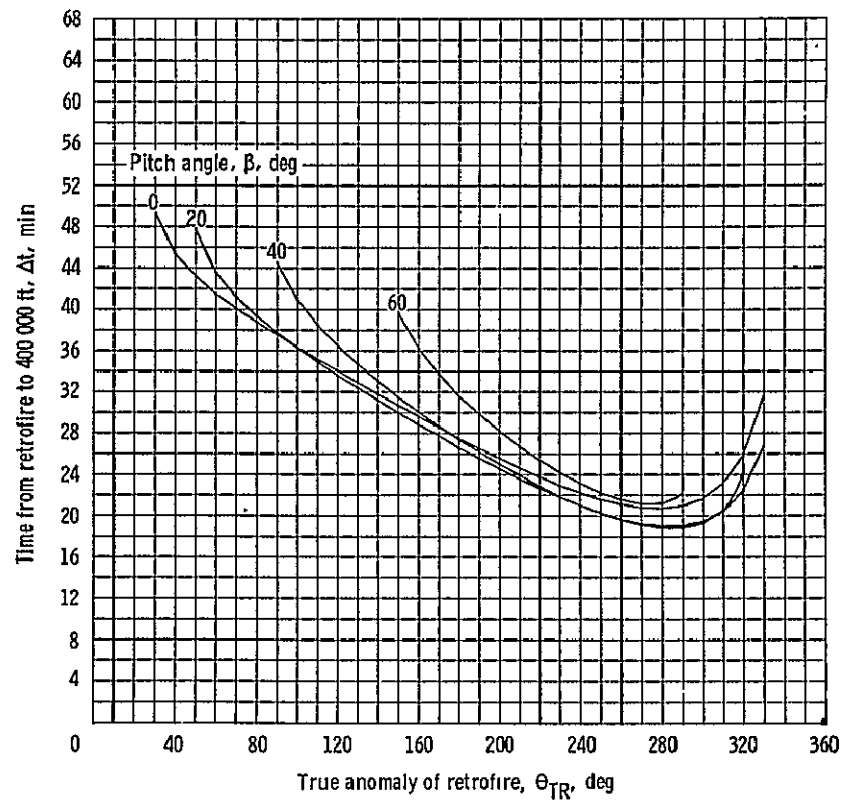
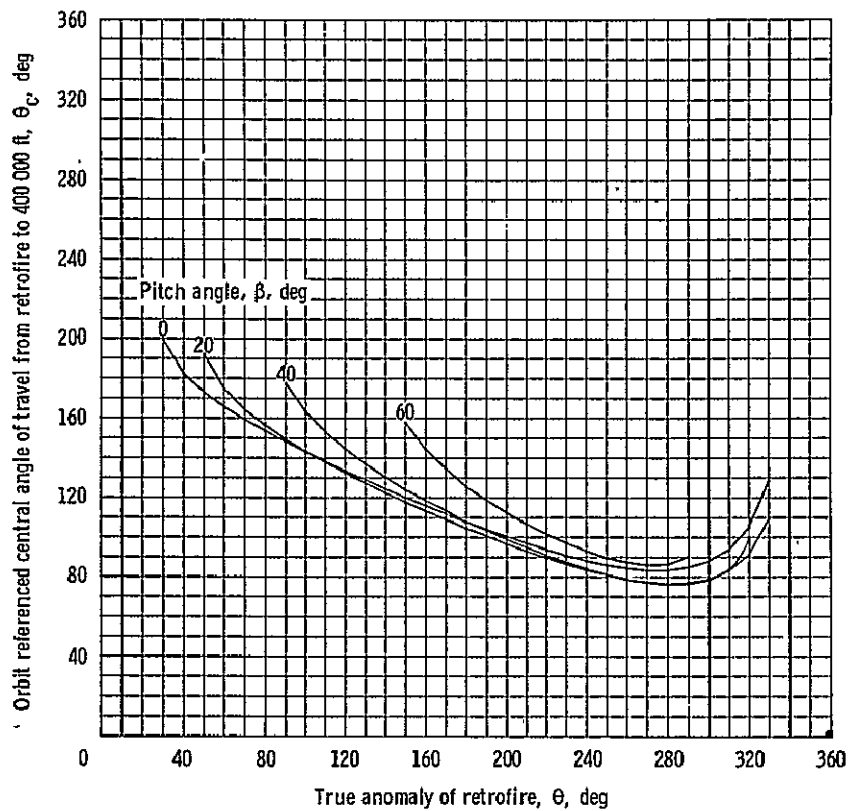
(b) Retrograde $\Delta V = 500$ fps.

Figure 23. - Continued.



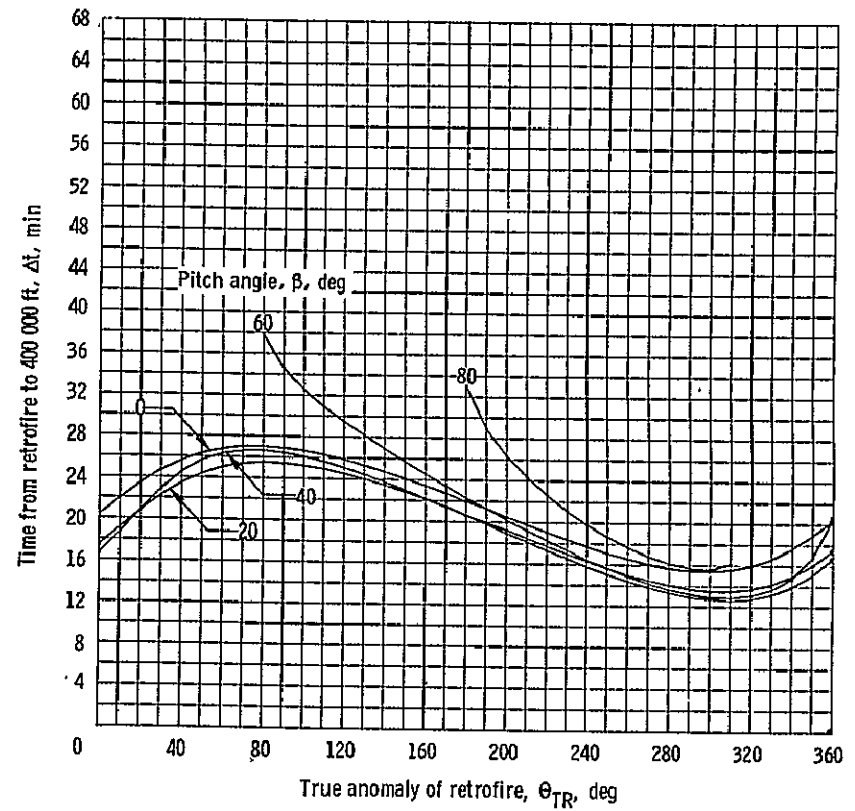
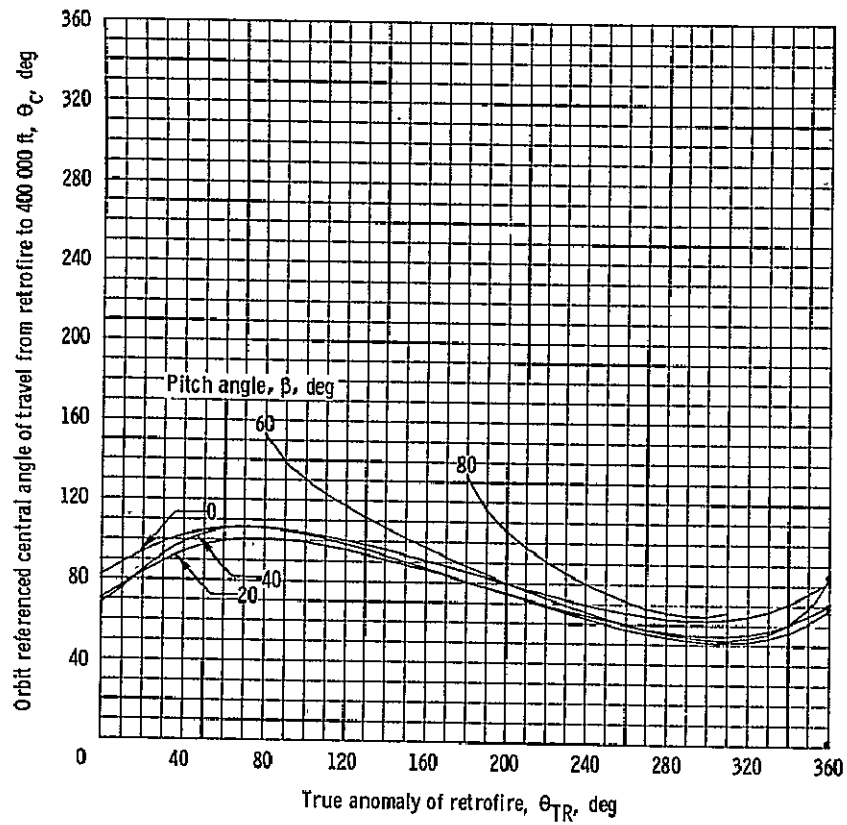
(c) Retrograde $\Delta V = 700$ fps.

Figure 23. - Concluded.



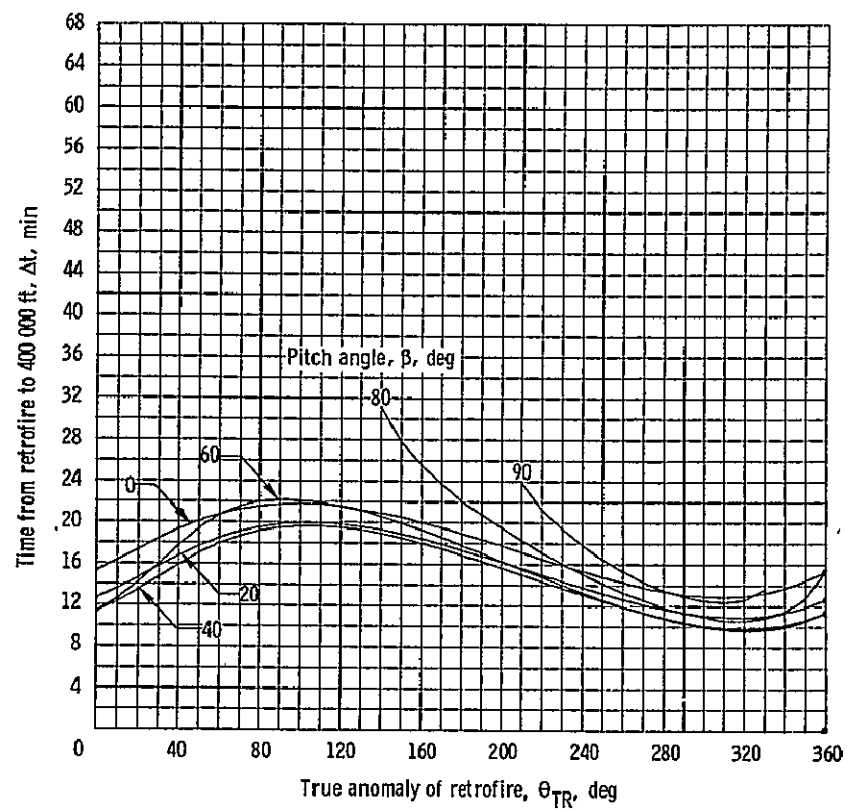
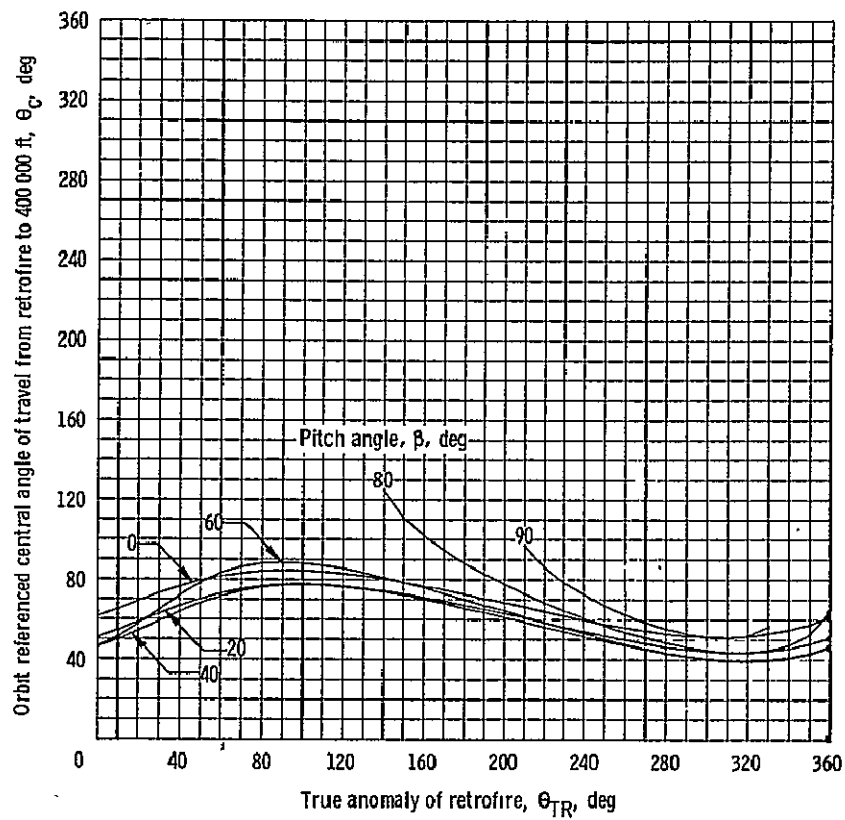
(a) Retrograde $\Delta V = 300$ fps.

Figure 24. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 250$ nautical miles and $h_p = 140$ nautical miles.



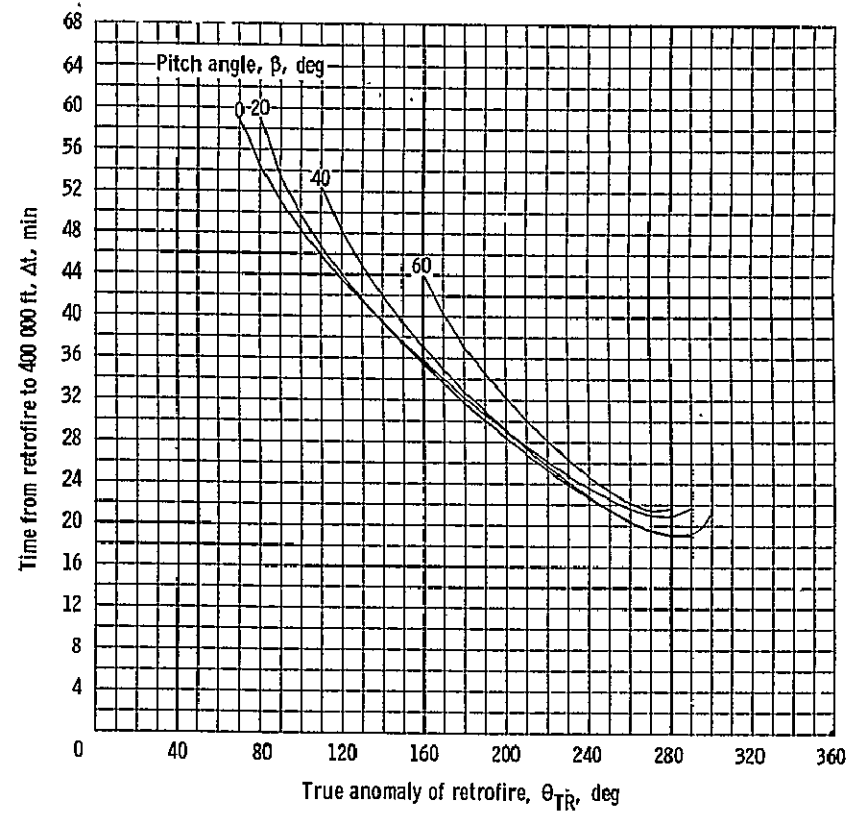
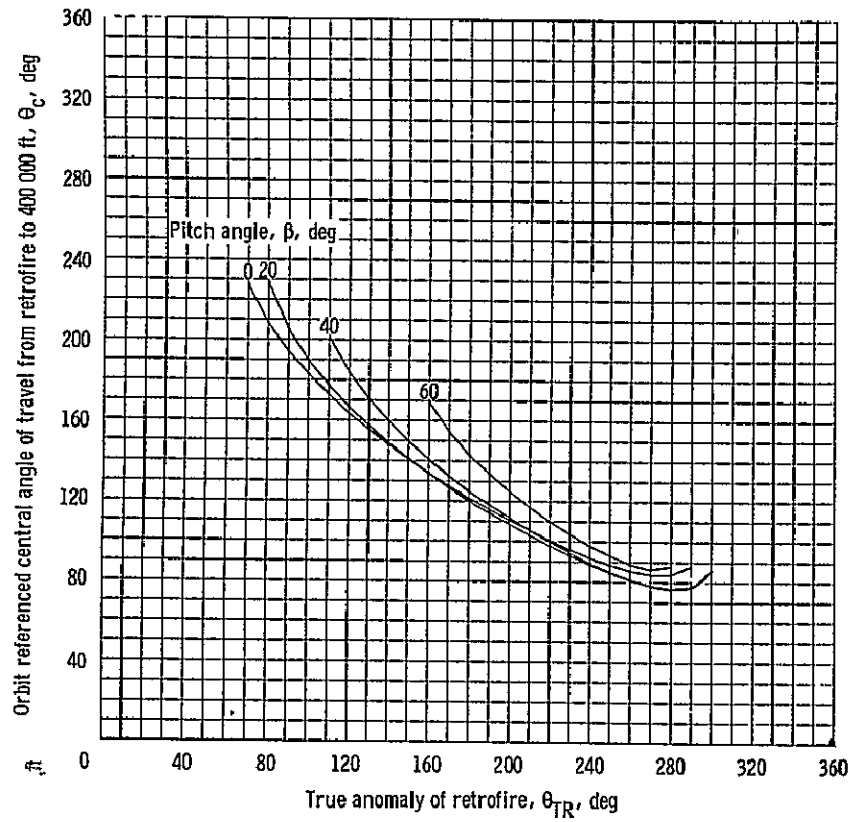
(b) Retrograde $\Delta V = 500$ fps.

Figure 24. - Continued.



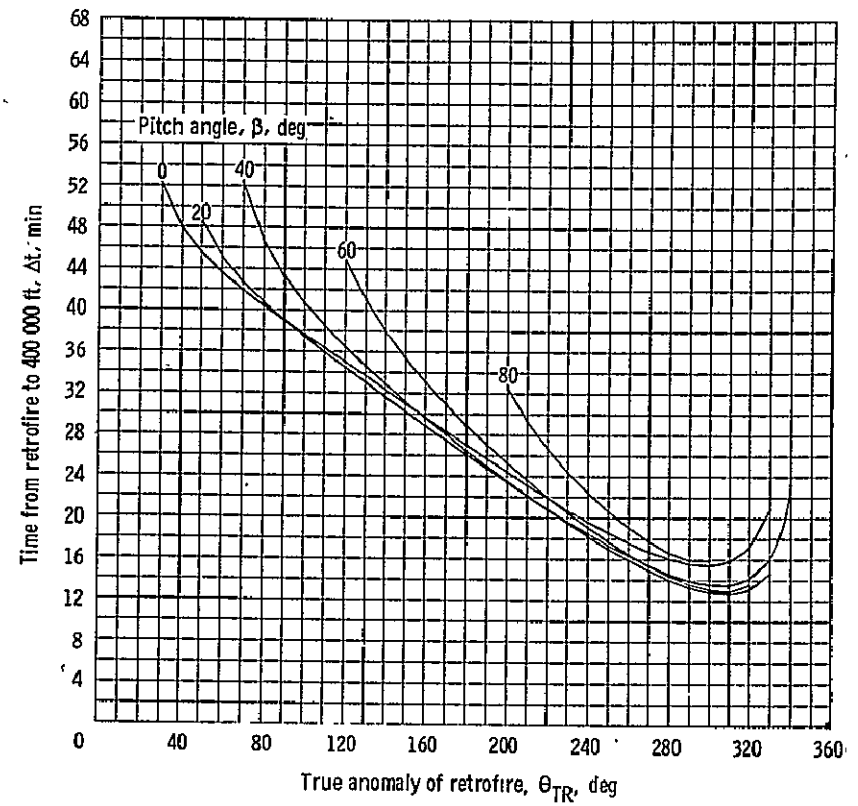
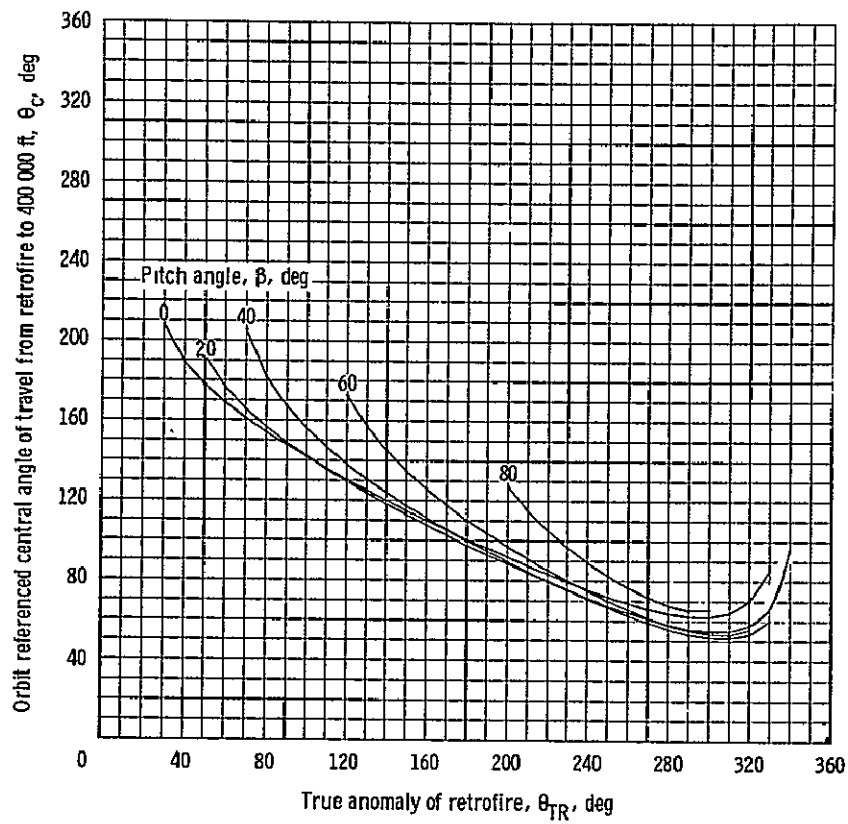
(c) Retrograde $\Delta V = 700$ fps.

Figure 24. - Concluded.



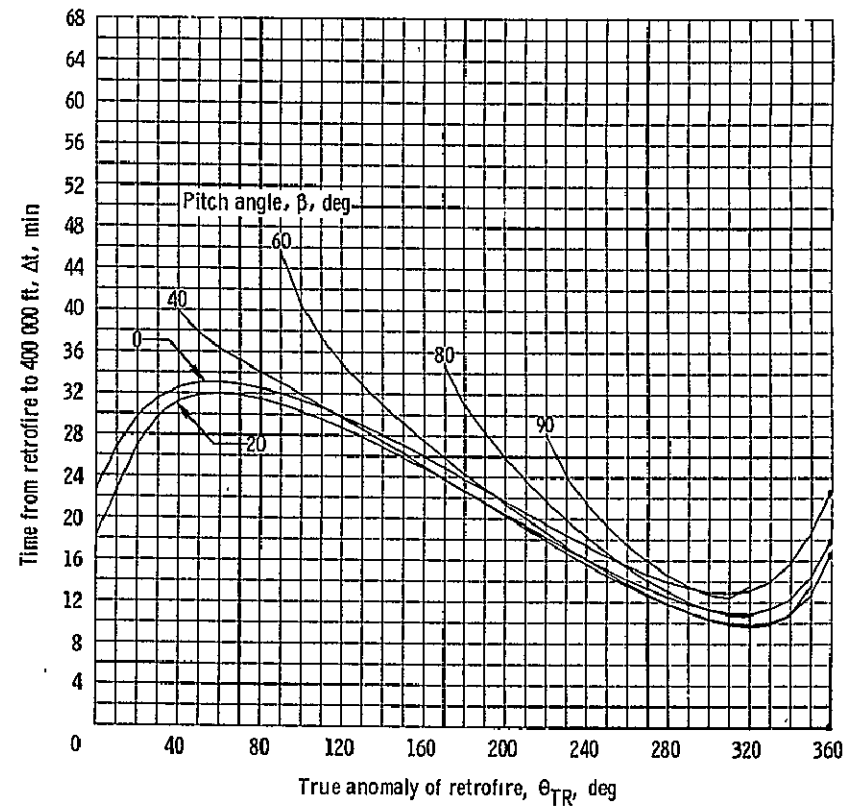
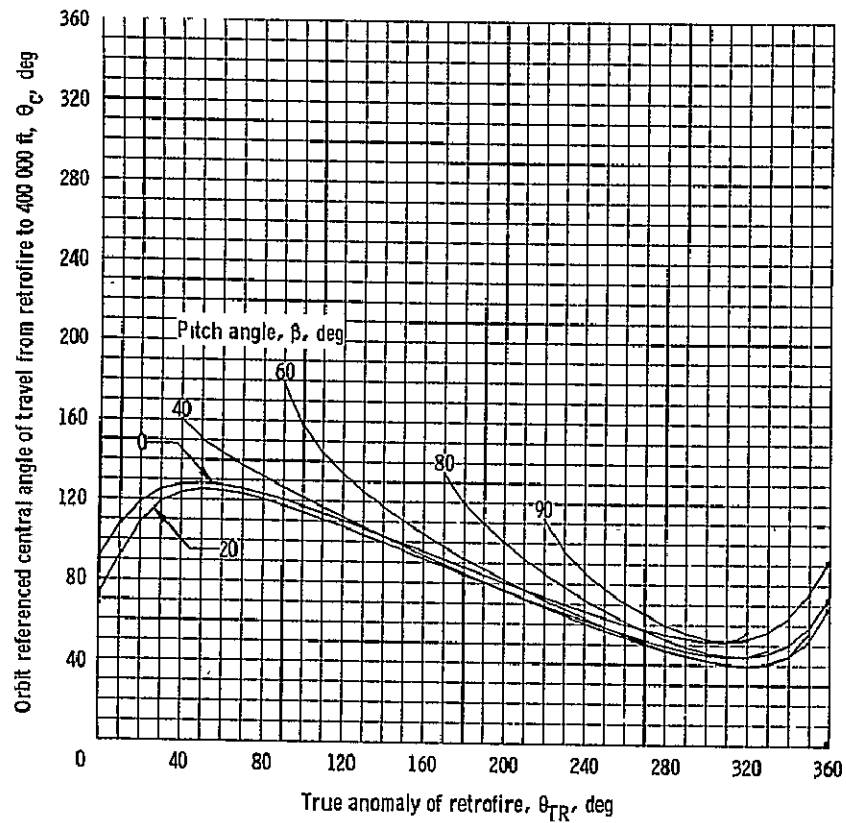
(a) Retrograde $\Delta V = 300$ fps.

Figure 25. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 400$ nautical miles and $h_p = 140$ nautical miles.



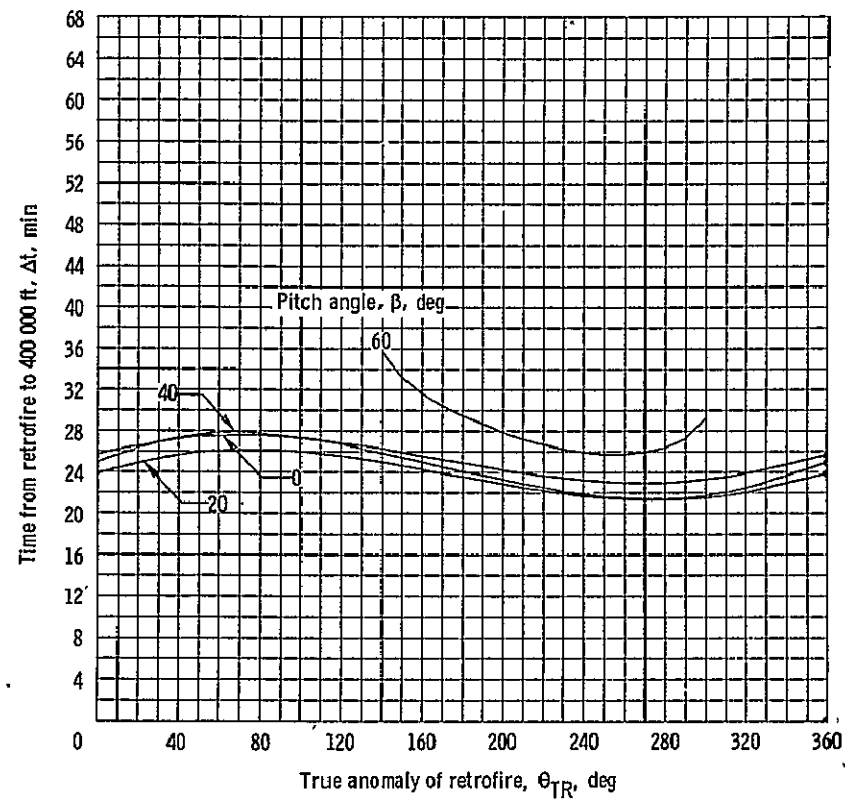
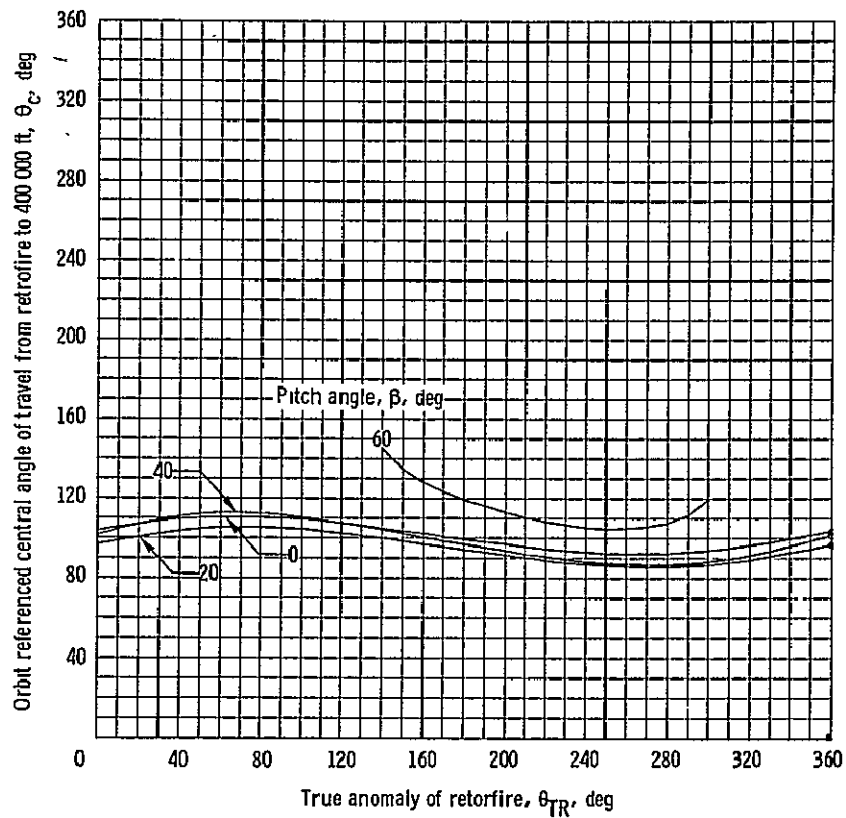
(b) Retrograde $\Delta V = 500$ fps.

Figure 25. - Continued.



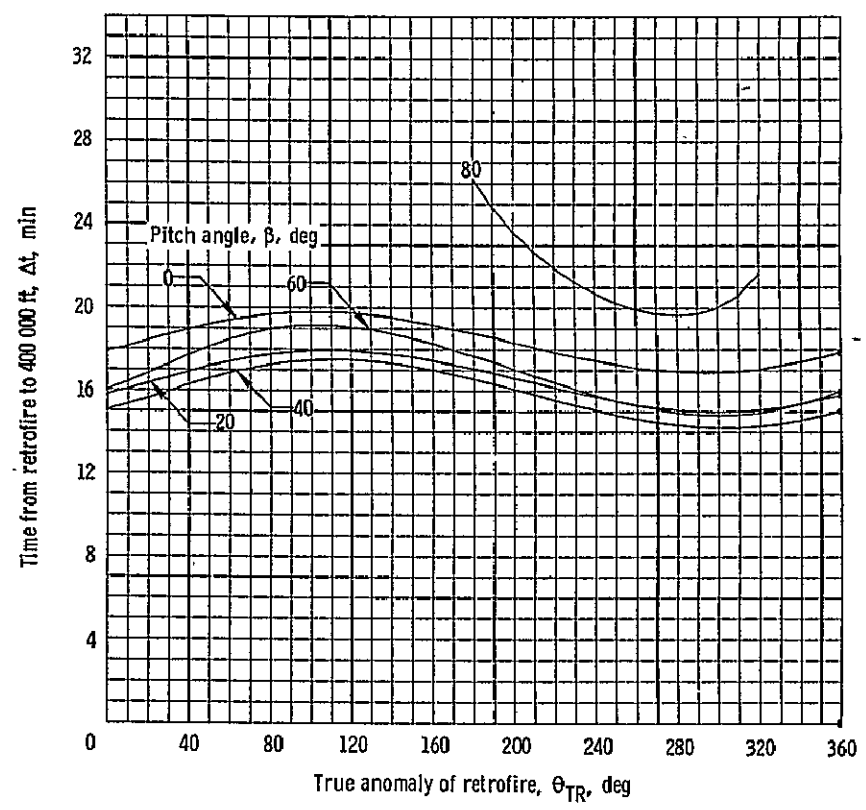
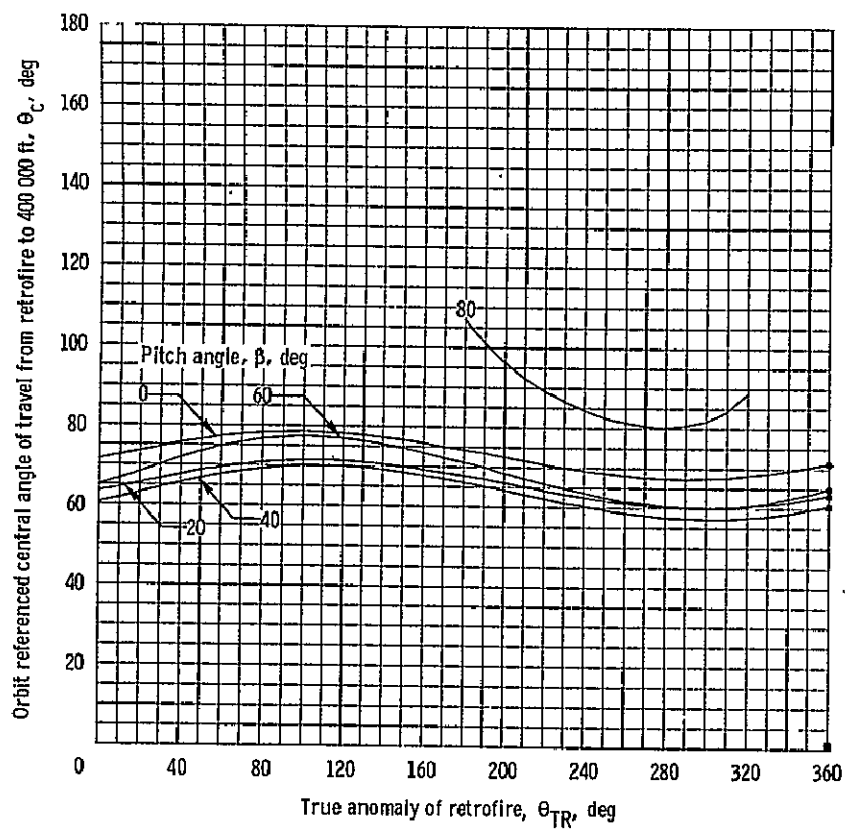
(c) Retrograde $\Delta V = 700$ fps.

Figure 25. - Concluded.



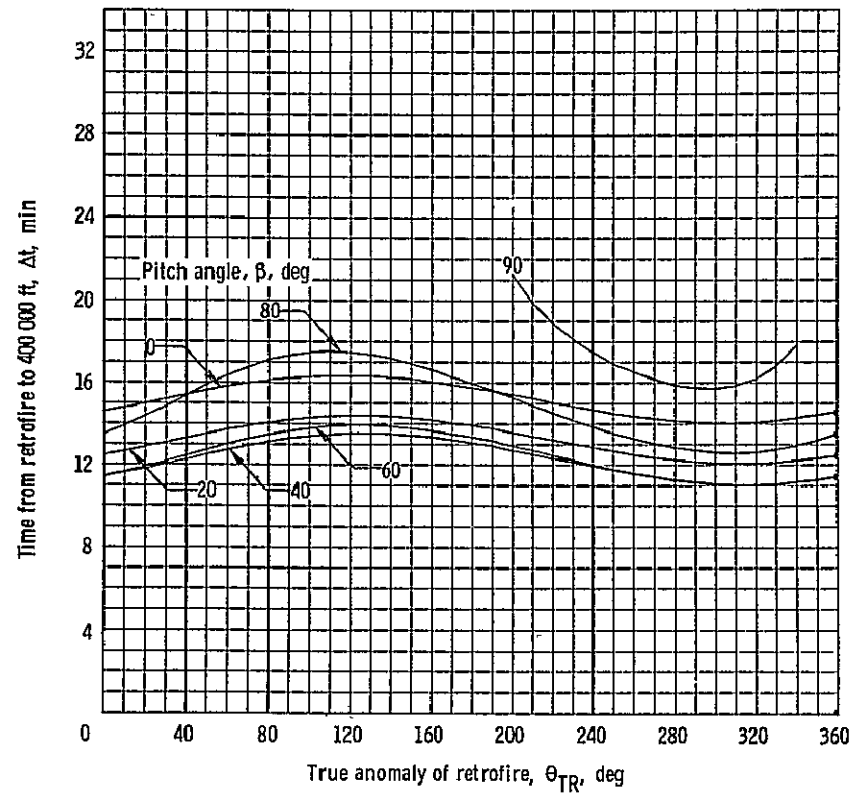
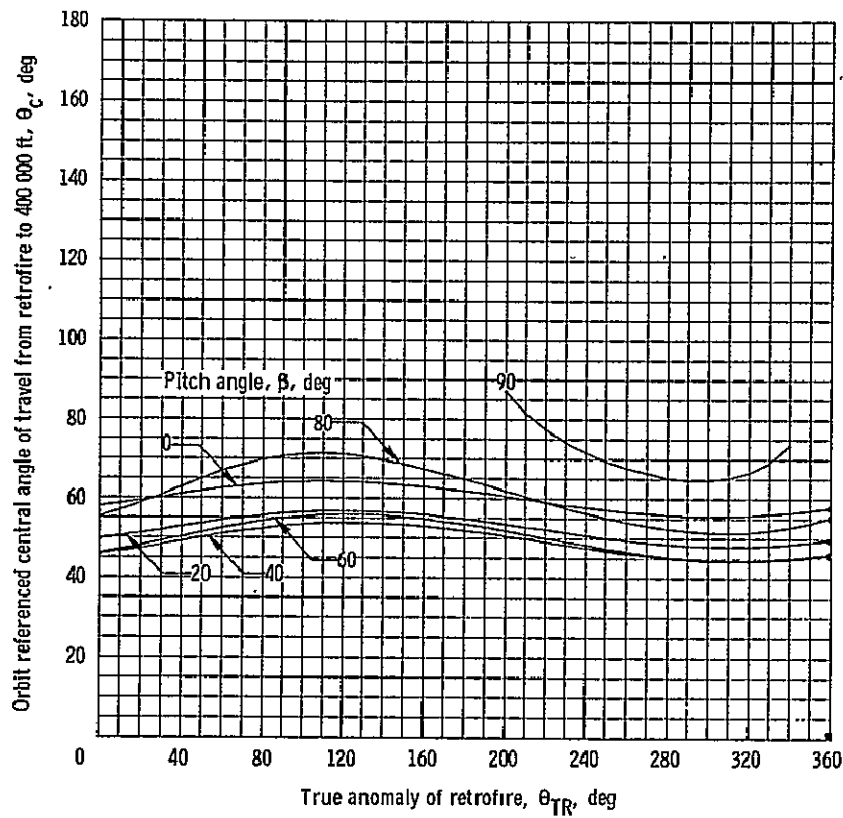
(a) Retrograde $\Delta V = 300$ fps.

Figure 26. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 180$ nautical miles and $h_n = 153$ nautical miles.



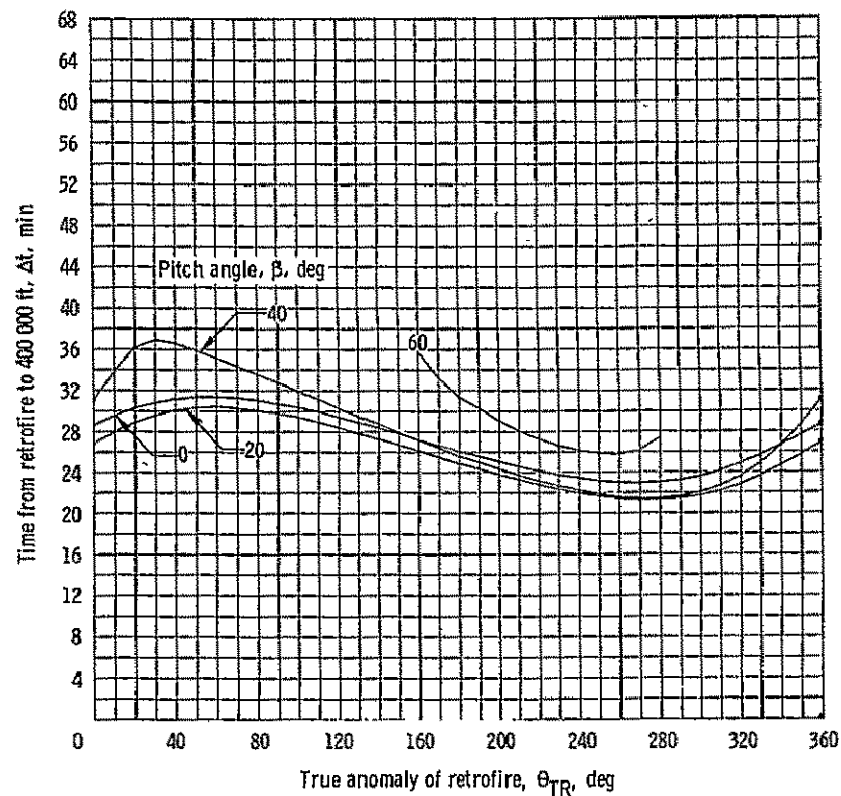
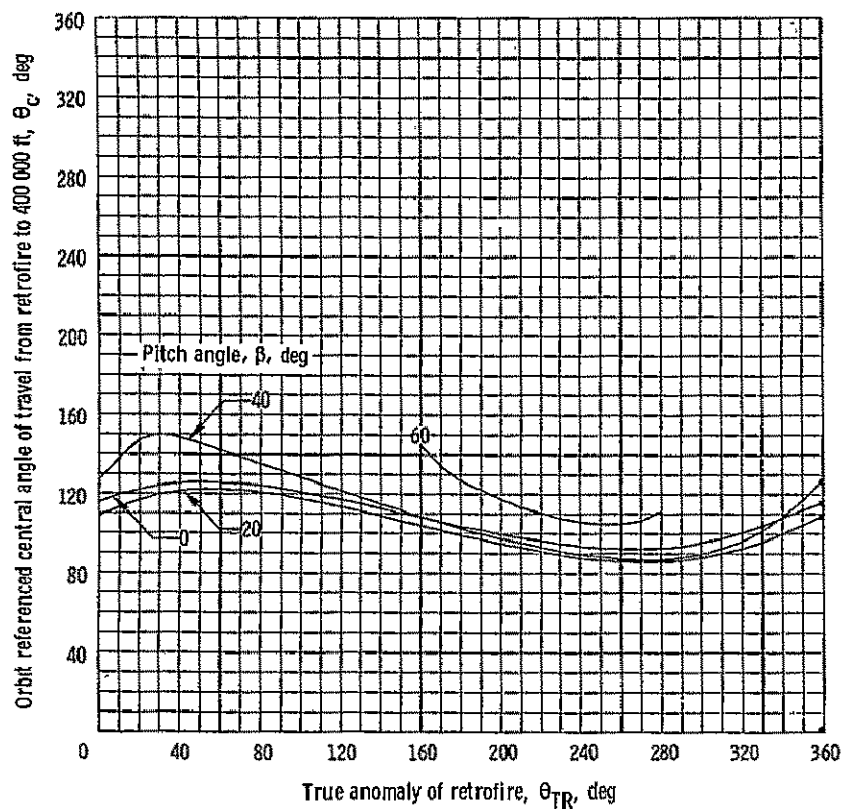
(b) Retrograde $\Delta V = 500$ fps.

Figure 26. - Continued.



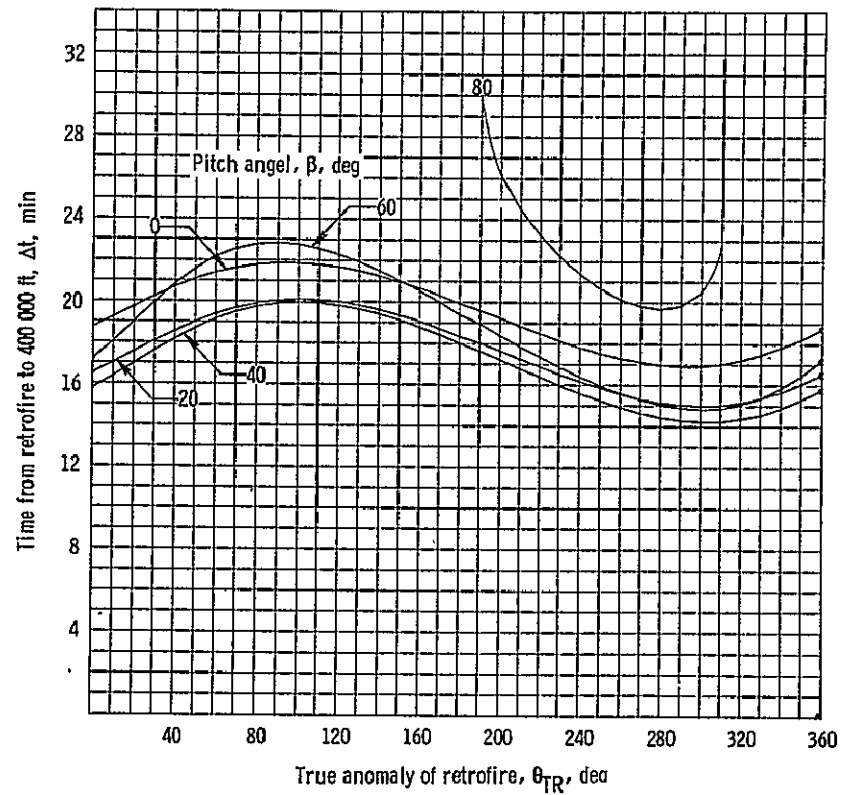
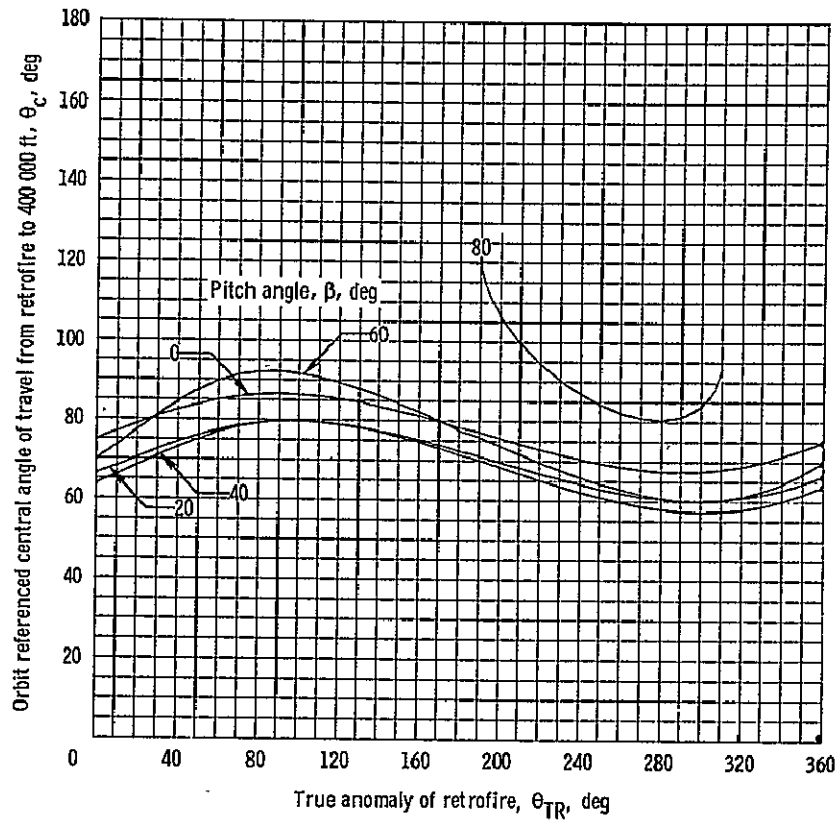
(c) Retrograde $\Delta V = 700$ fps.

Figure 26. - Concluded.



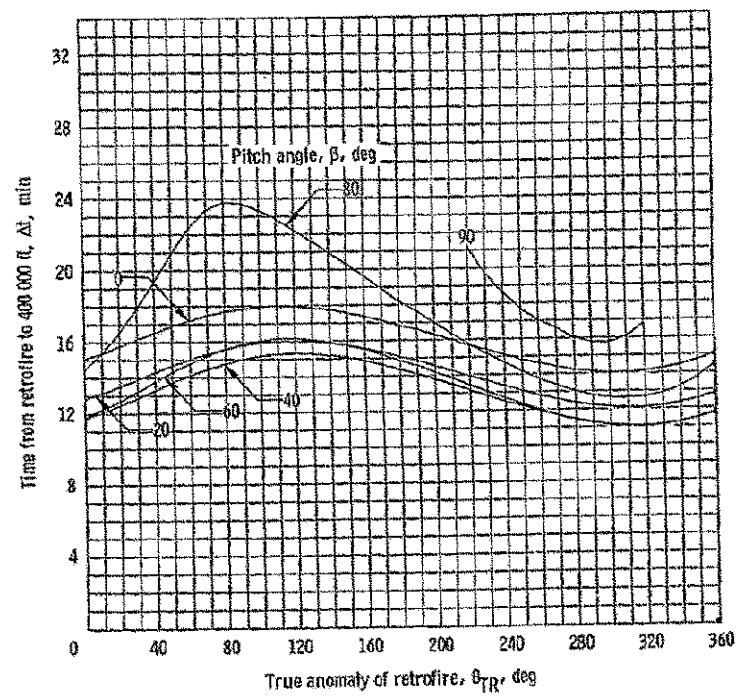
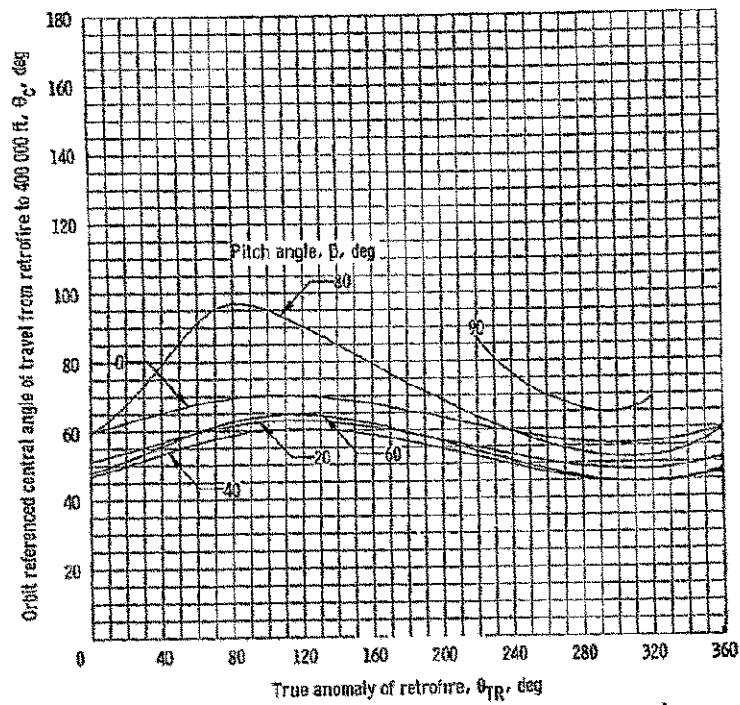
(a) Retrograde AV = 300 fps.

Figure 27. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde AV; $h_a = 200$ nautical miles and $h_p = 153$ nautical miles.



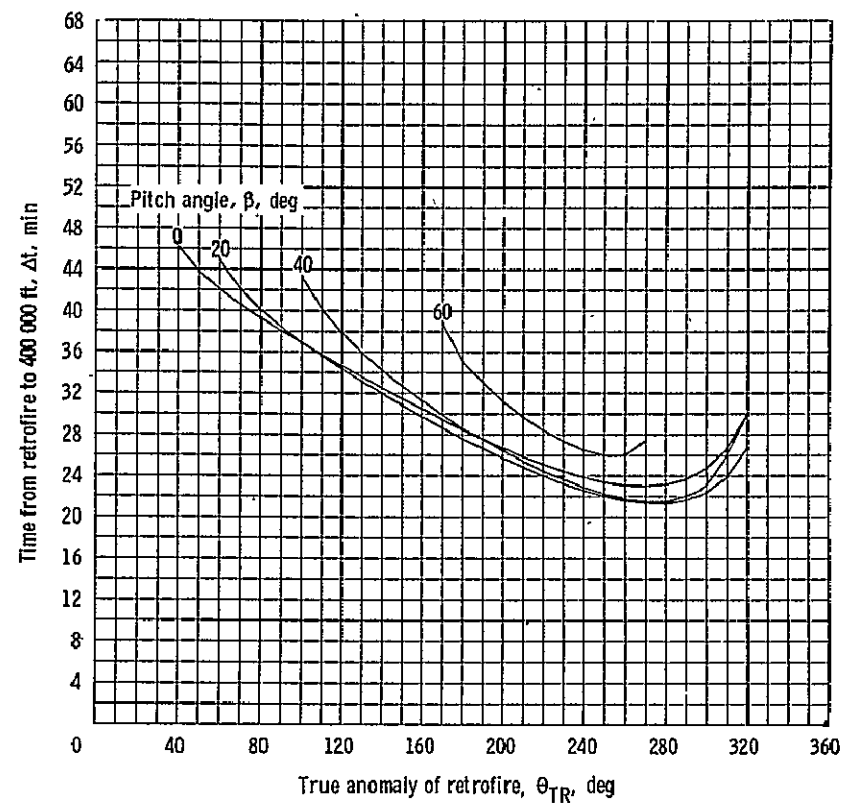
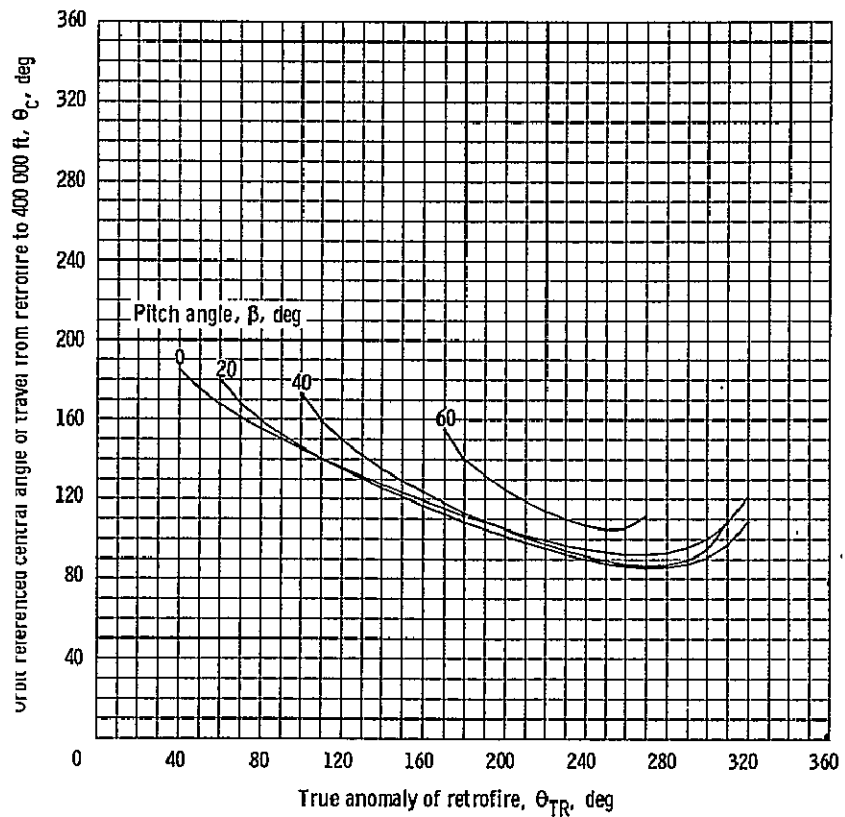
(b) Retrograde $\Delta V = 500$ fps.

Figure 27. - Continued.



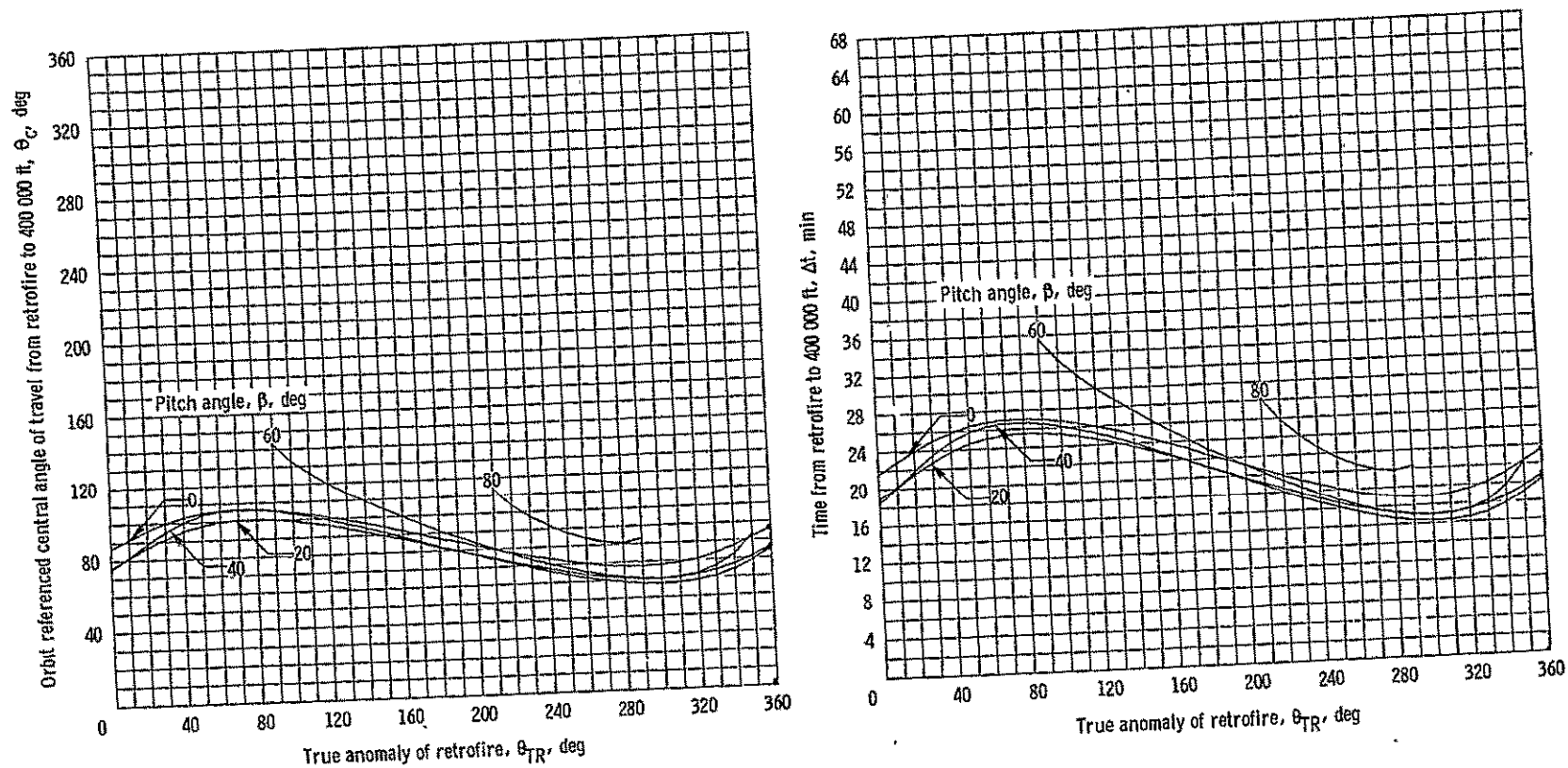
(c) Retrograde $\Delta V = 700$ fps.

Figure 27, ~ Concluded.



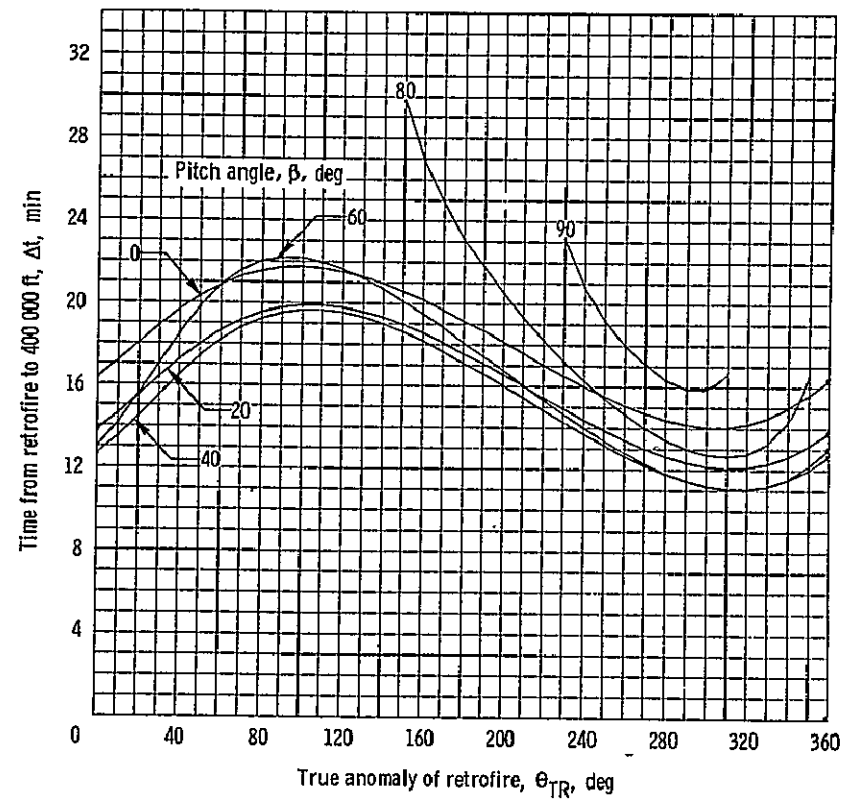
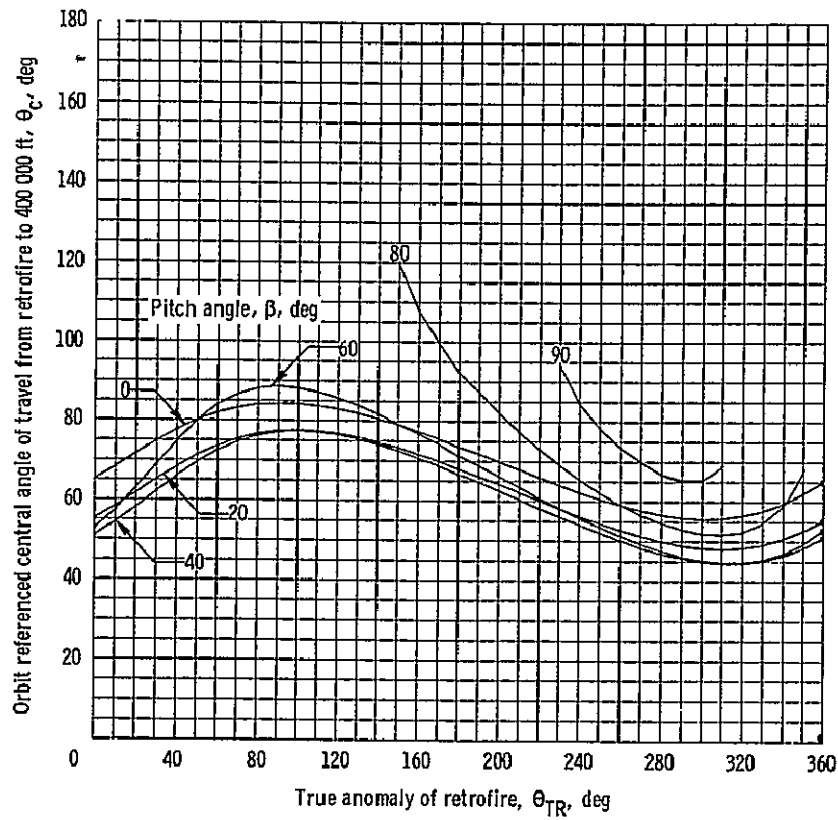
(a) Retrograde $\Delta V = 300$ fps.

Figure 28. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 250$ nautical miles and $h_p = 153$ nautical miles.



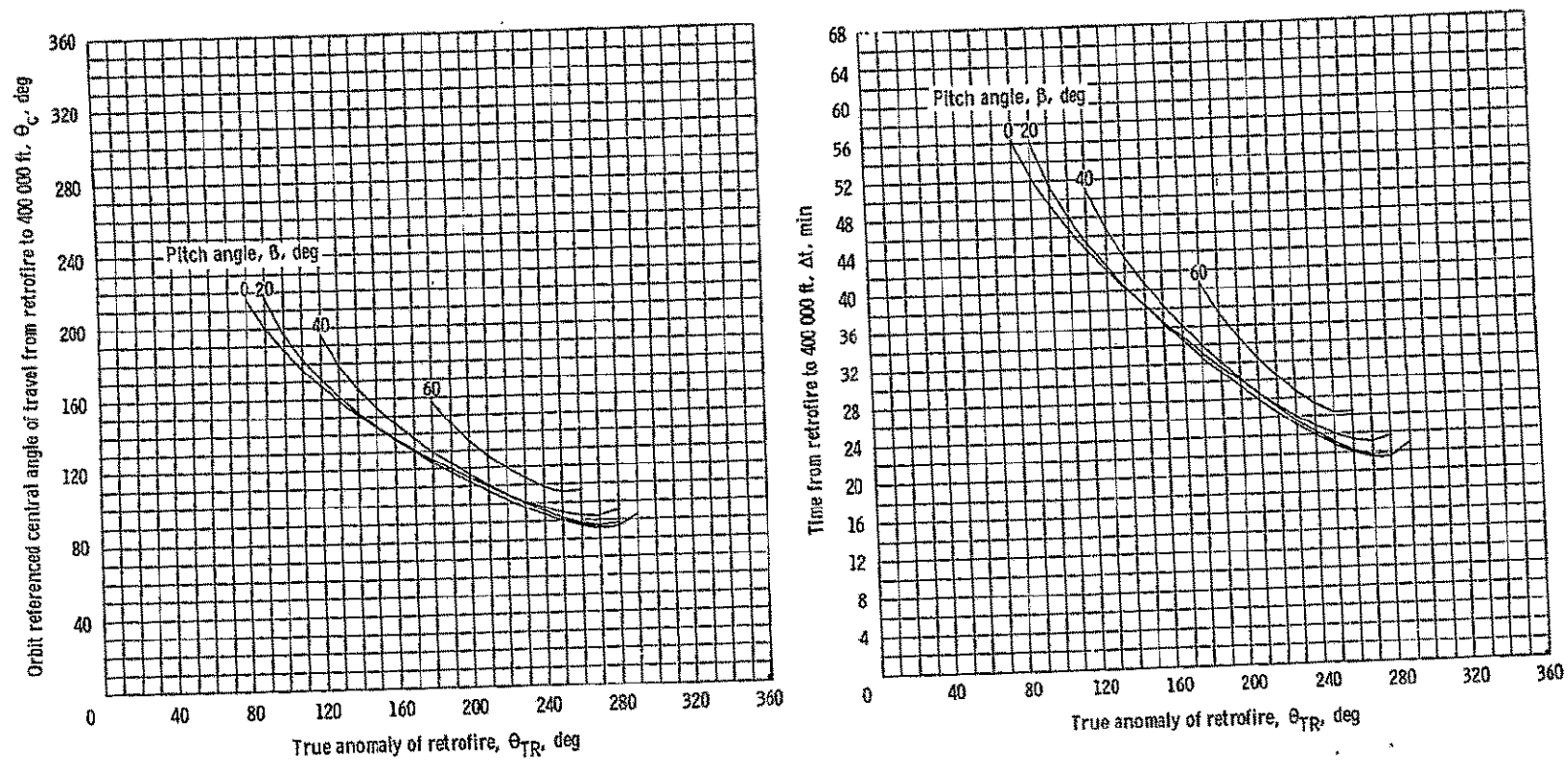
(b) Retrograde $\Delta V = 500$ fps.

Figure 28. - Continued.



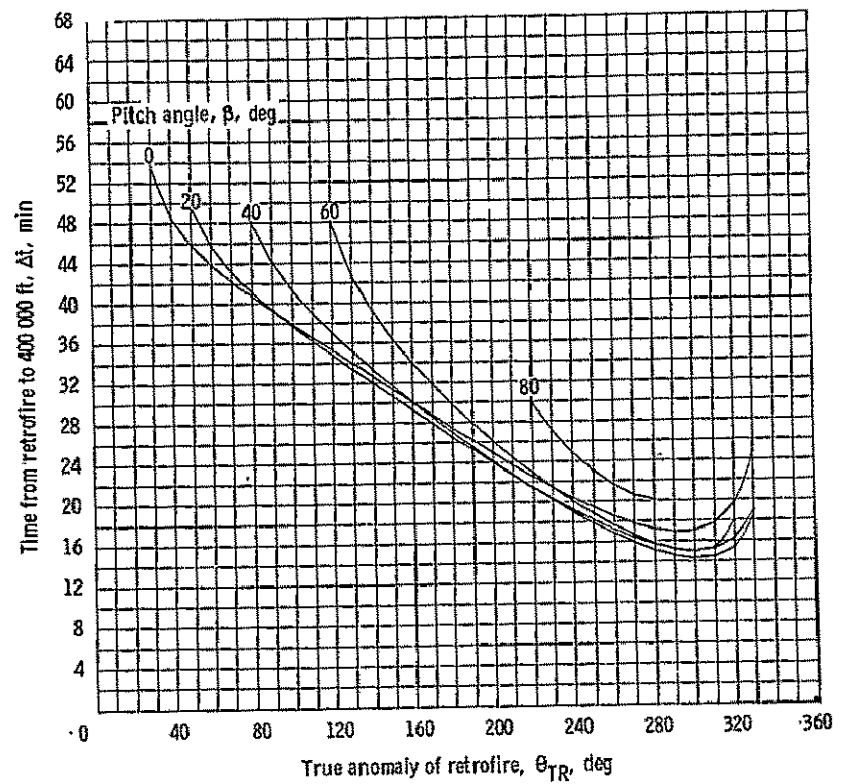
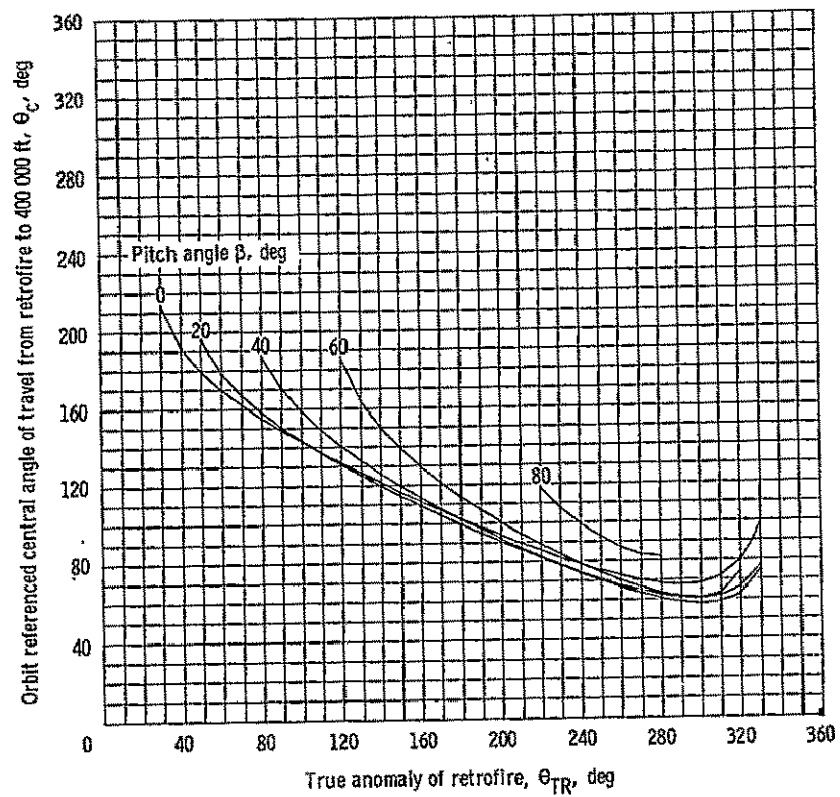
(c) Retrograde $\Delta V = 700$ fps.

Figure 28. - Concluded.



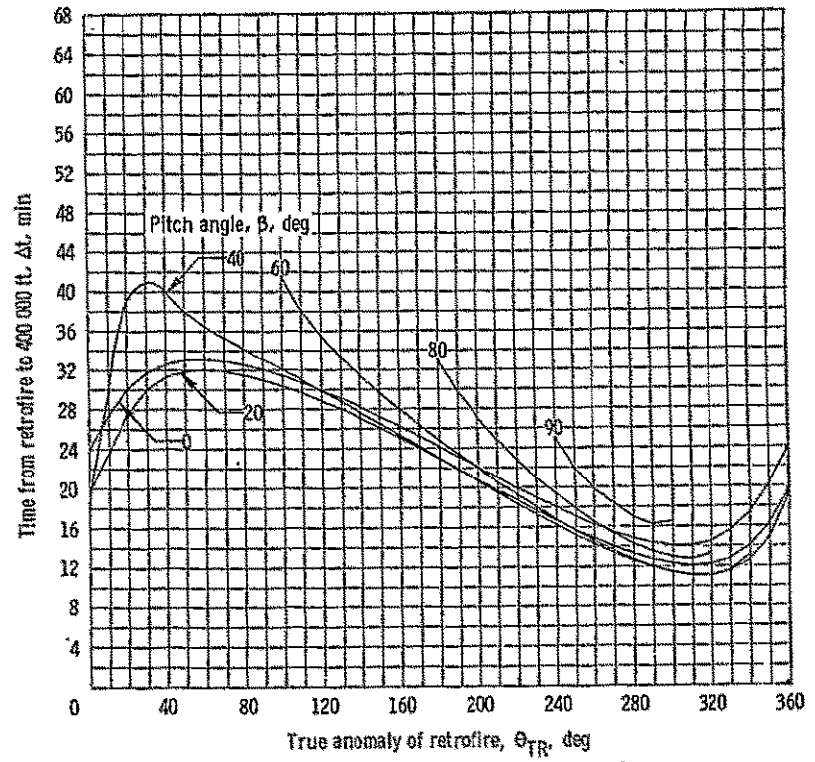
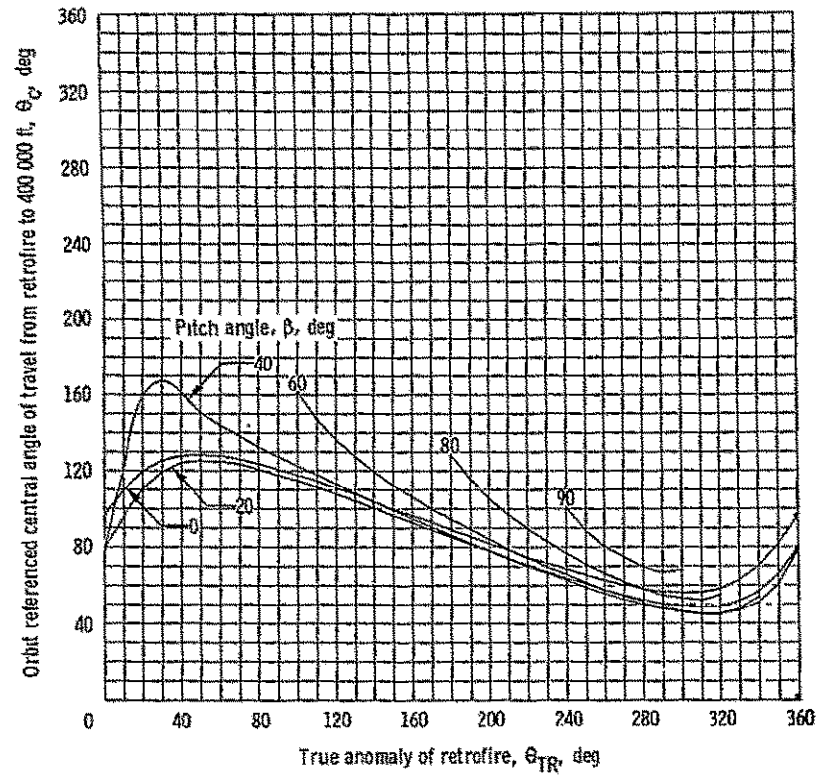
(a) Retrograde $\Delta V = 300$ fps.

Figure 29. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 400$ nautical miles and $h_p = 153$ nautical miles.



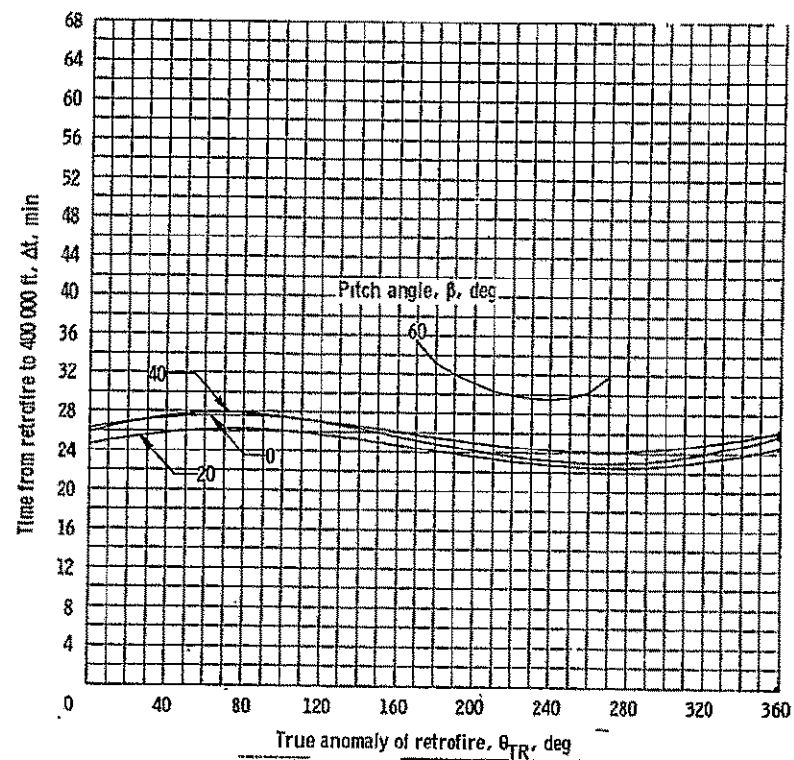
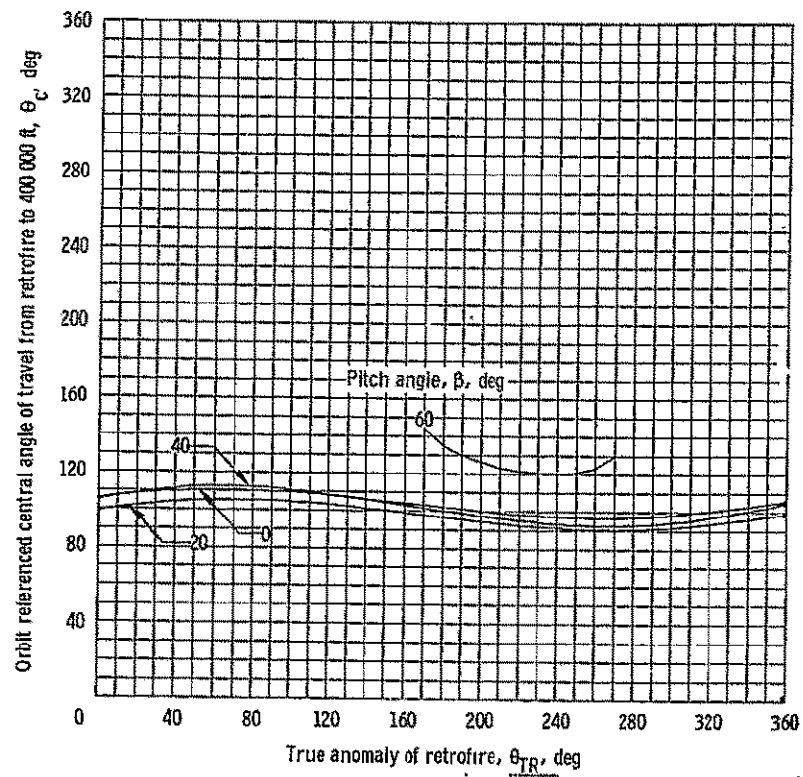
(b) Retrograde $\Delta V = 500$ fps.

Figure 29. - Continued.



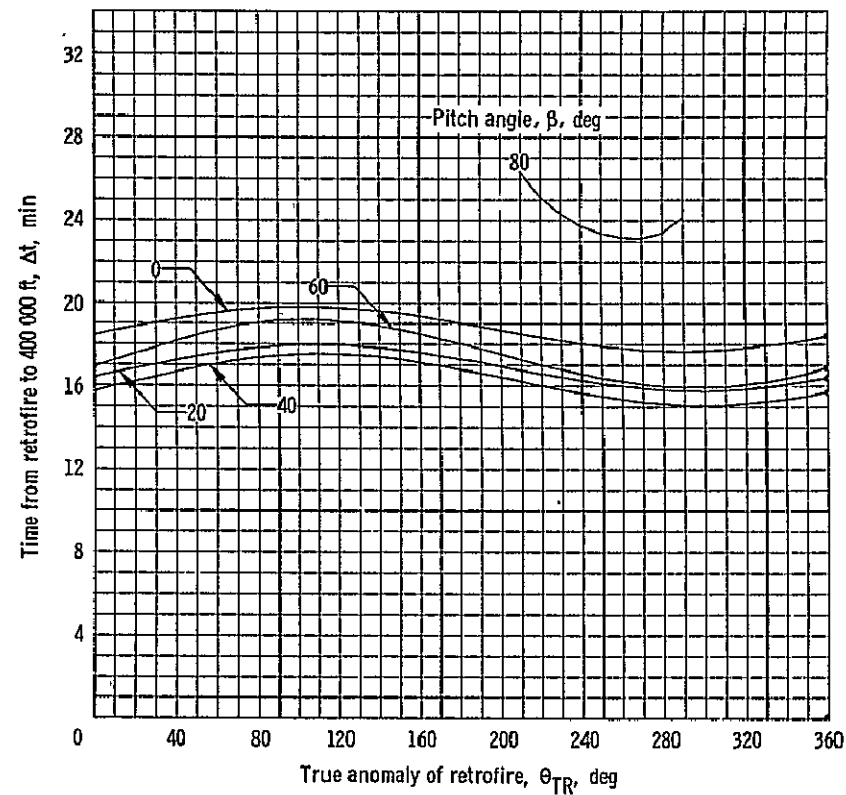
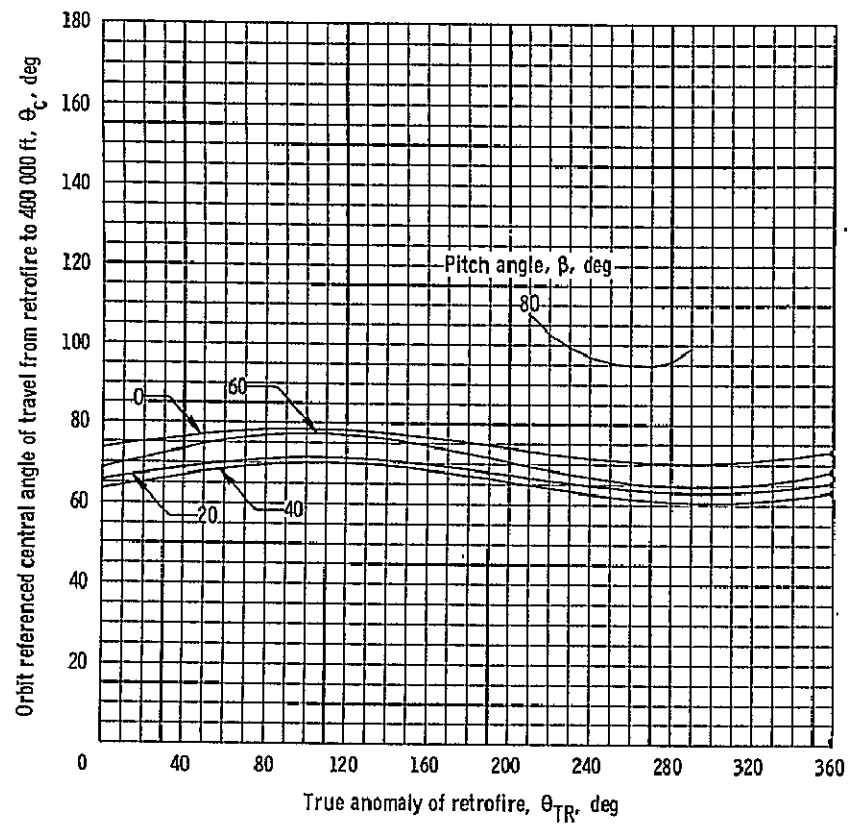
(c) Retrograde $\Delta V = 700$ fps.

Figure 29. - Concluded.



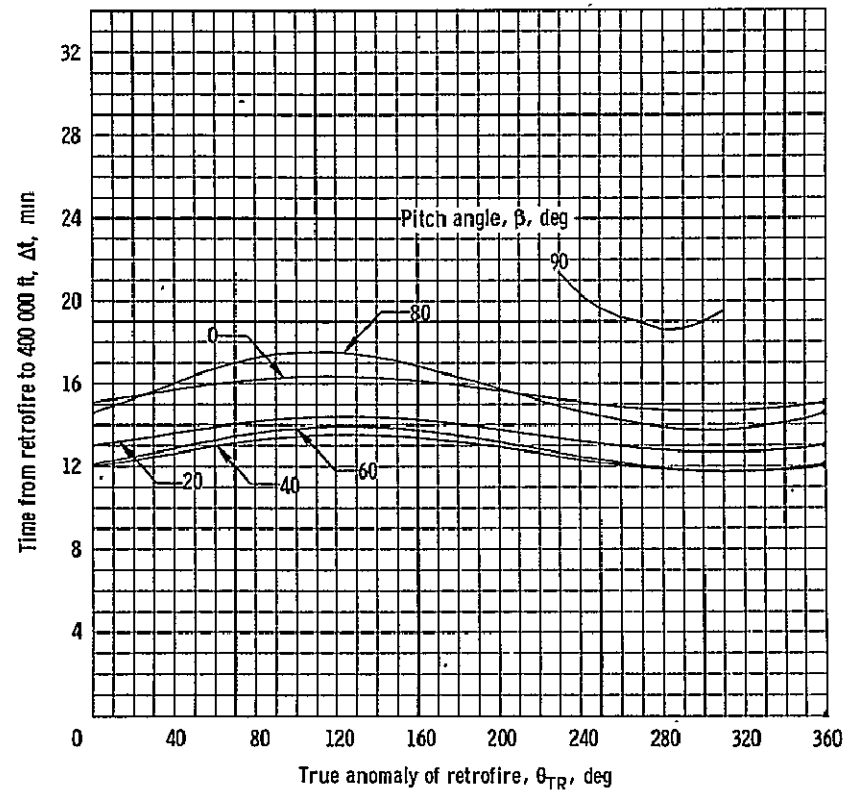
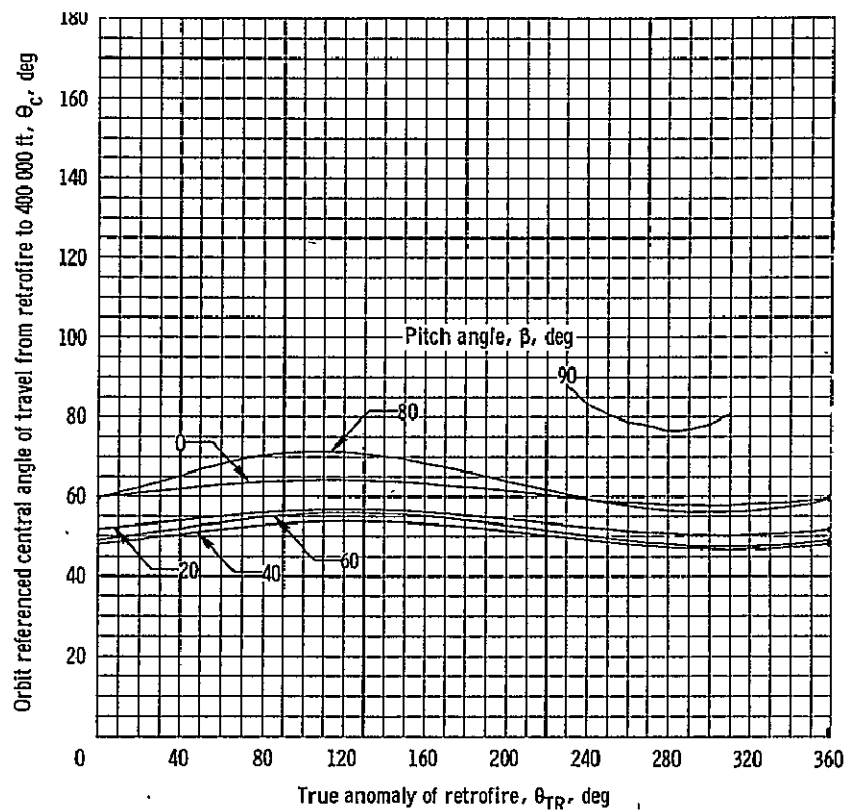
(a) Retrograde $\Delta V = 300$ fps.

Figure 30. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 180$ nautical miles and $h_p = 160$ nautical miles.



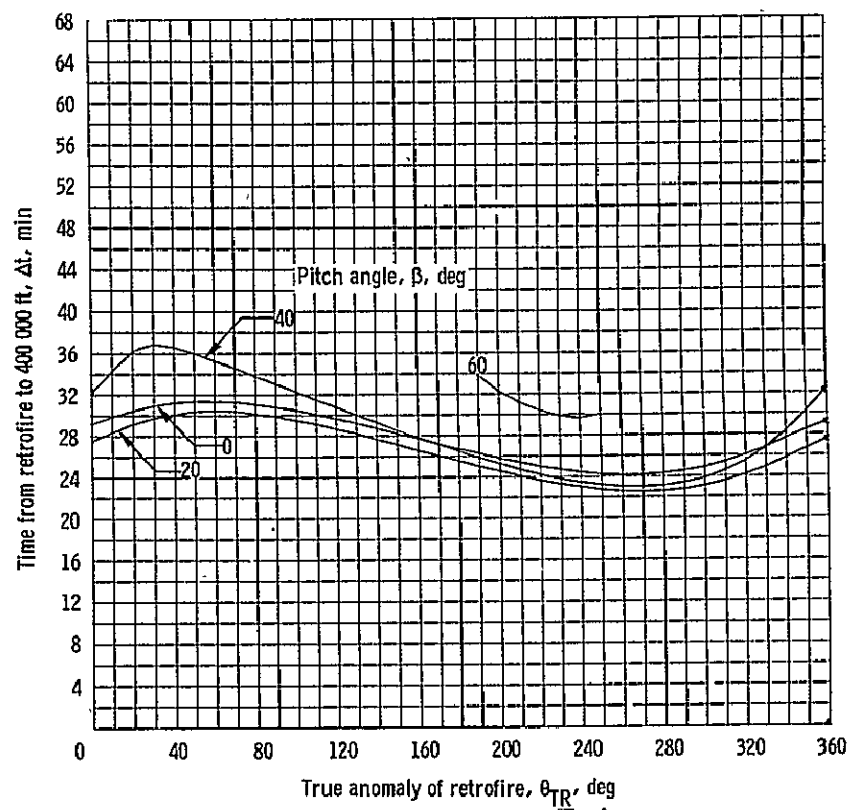
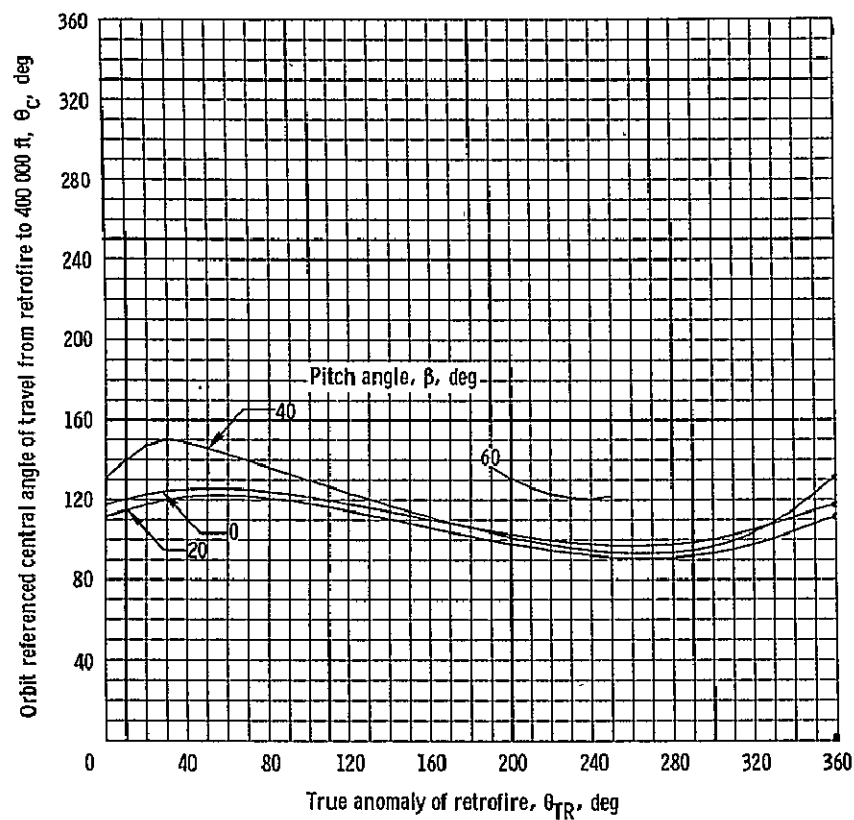
(b) Retrograde $\Delta V = 500$ fps.

Figure 30. - Continued.



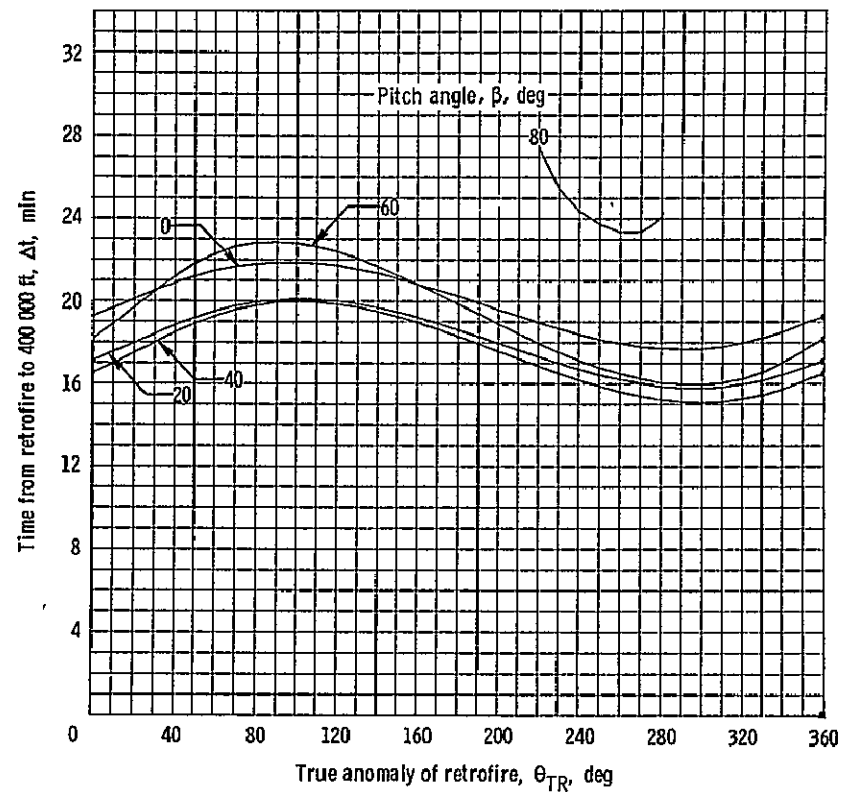
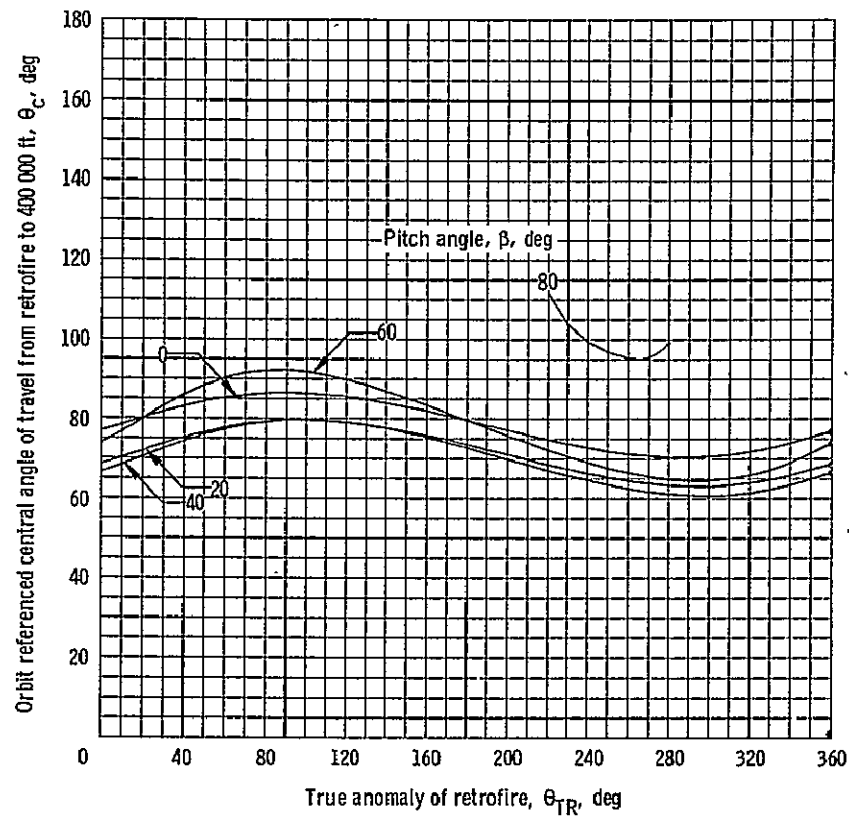
(c) Retrograde $\Delta V = 700$ fps.

Figure 30. - Concluded.



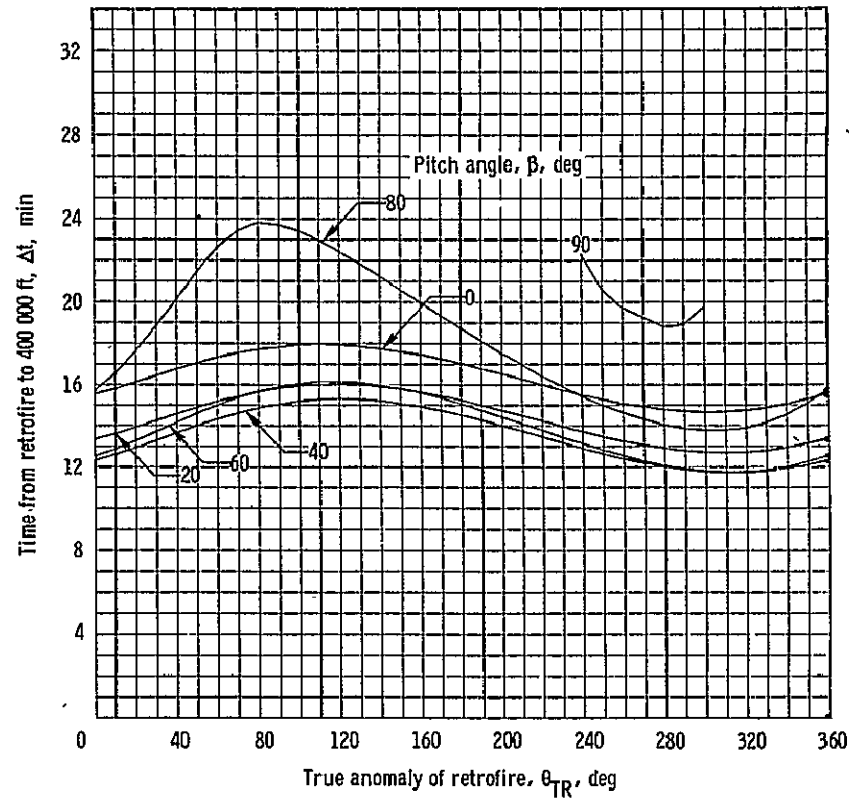
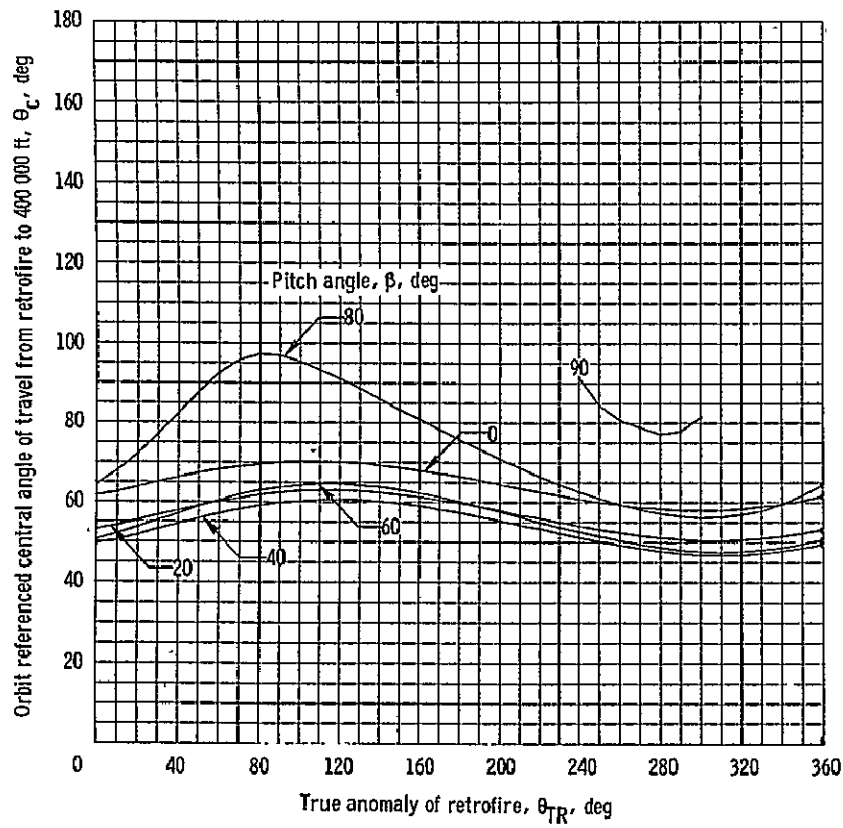
(a) Retrograde $\Delta V = 300$ fps.

Figure 31. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 200$ nautical miles and $h_p = 160$ nautical miles.



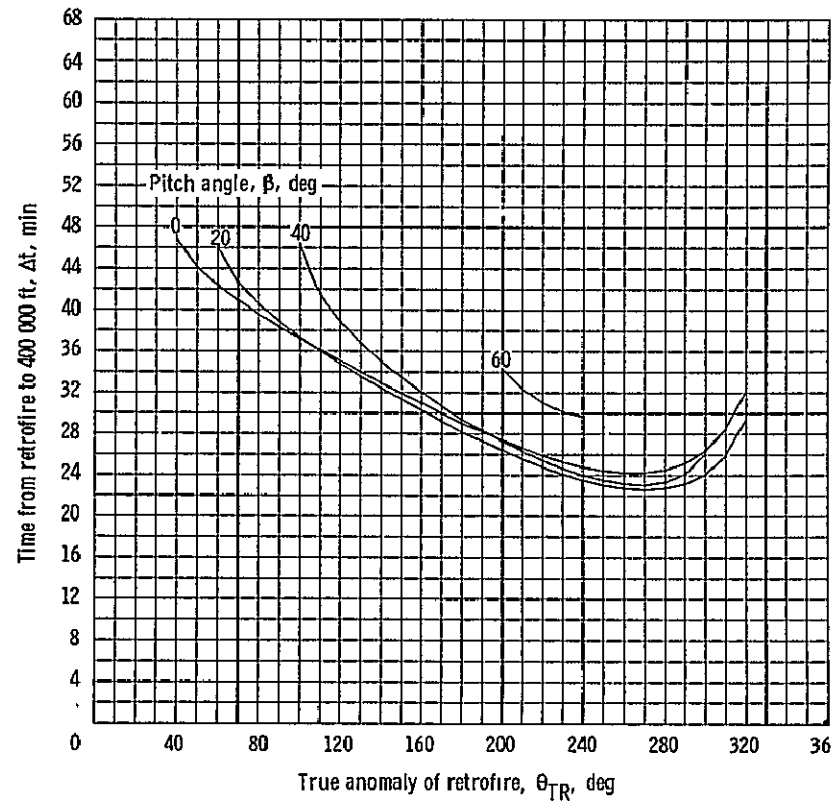
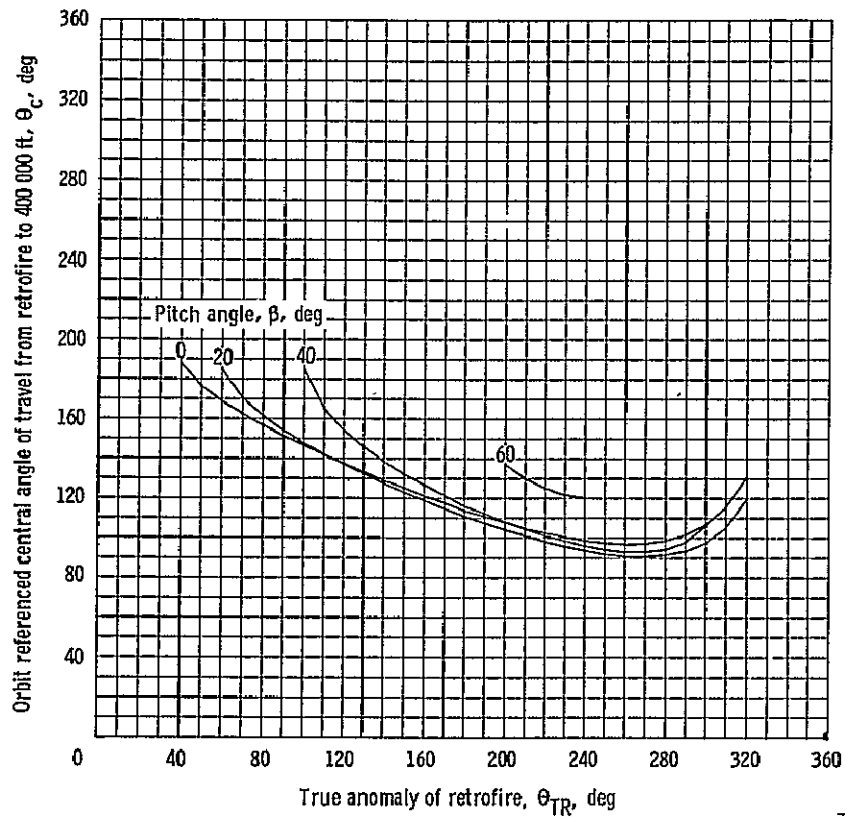
(b) Retrograde $\Delta V = 500$ fps.

Figure 31. - Continued.



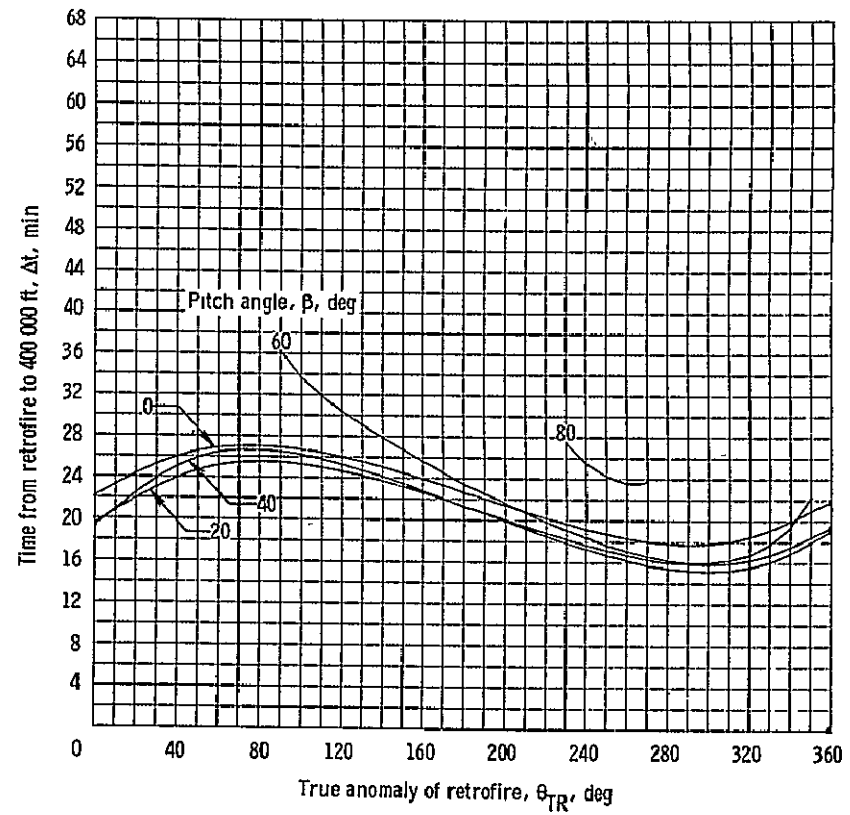
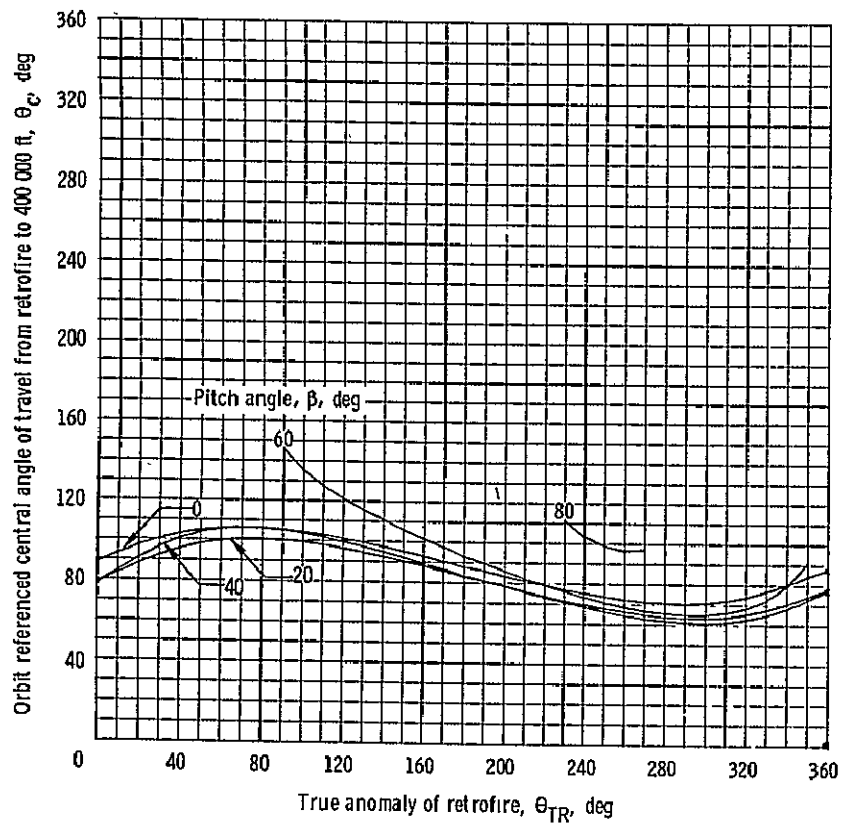
(c) Retrograde $\Delta V = 700$ fps.

Figure 31. - Concluded.



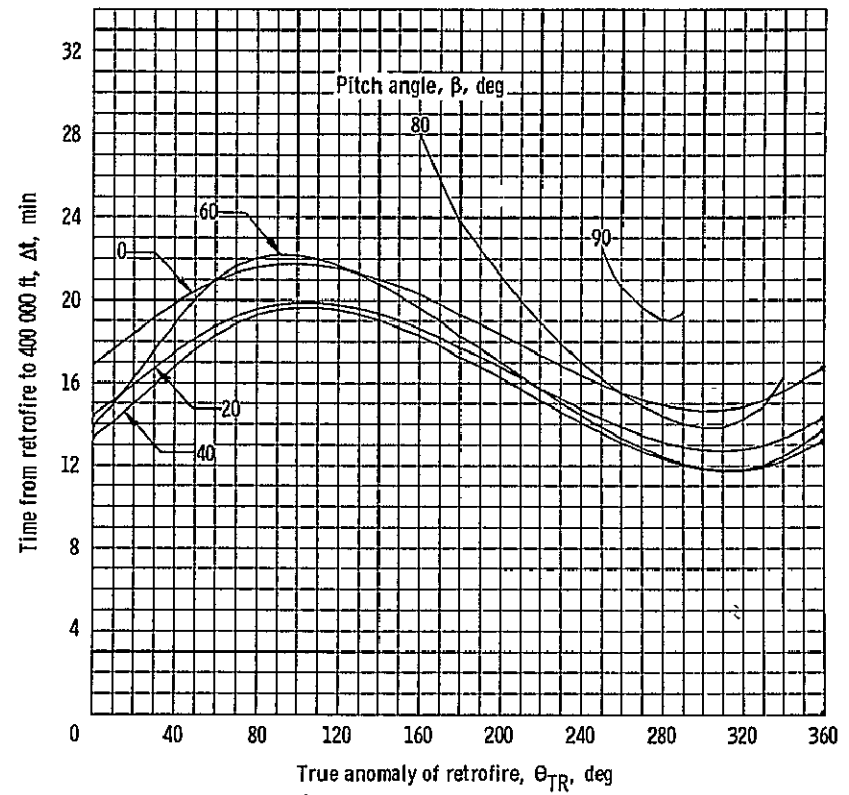
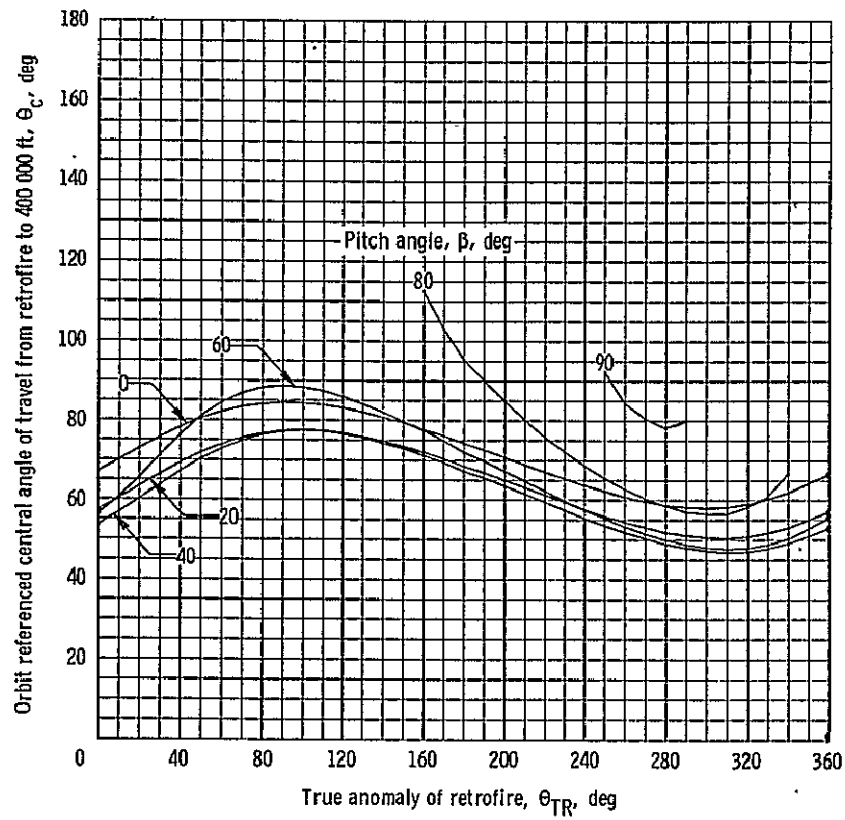
(a) Retrograde $\Delta V = 300$ fps.

Figure 32. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 250$ nautical miles and $h_p = 160$ nautical miles.



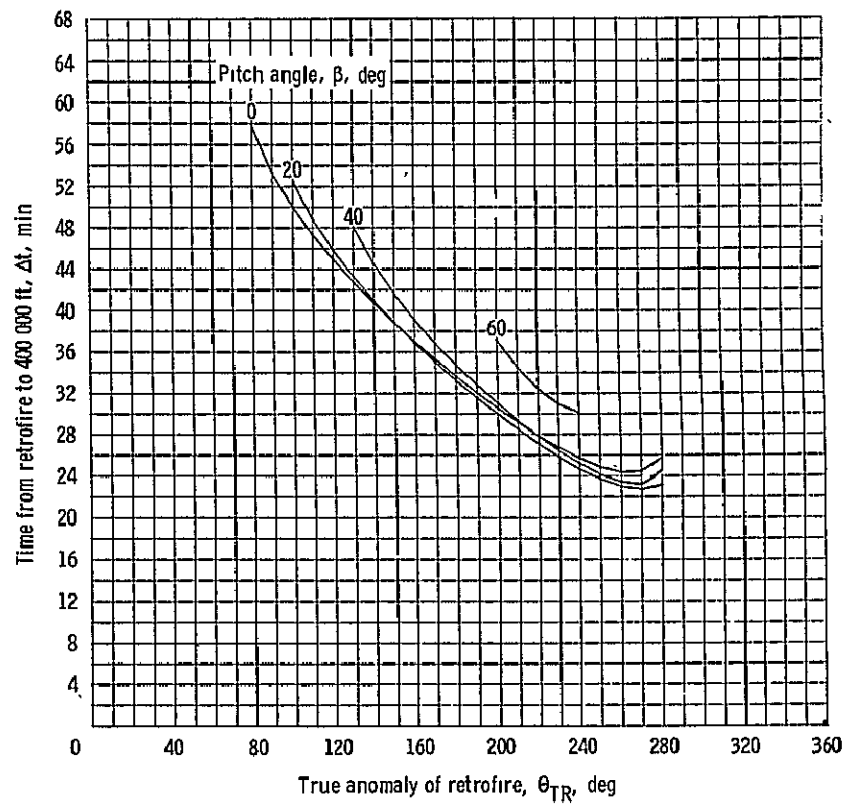
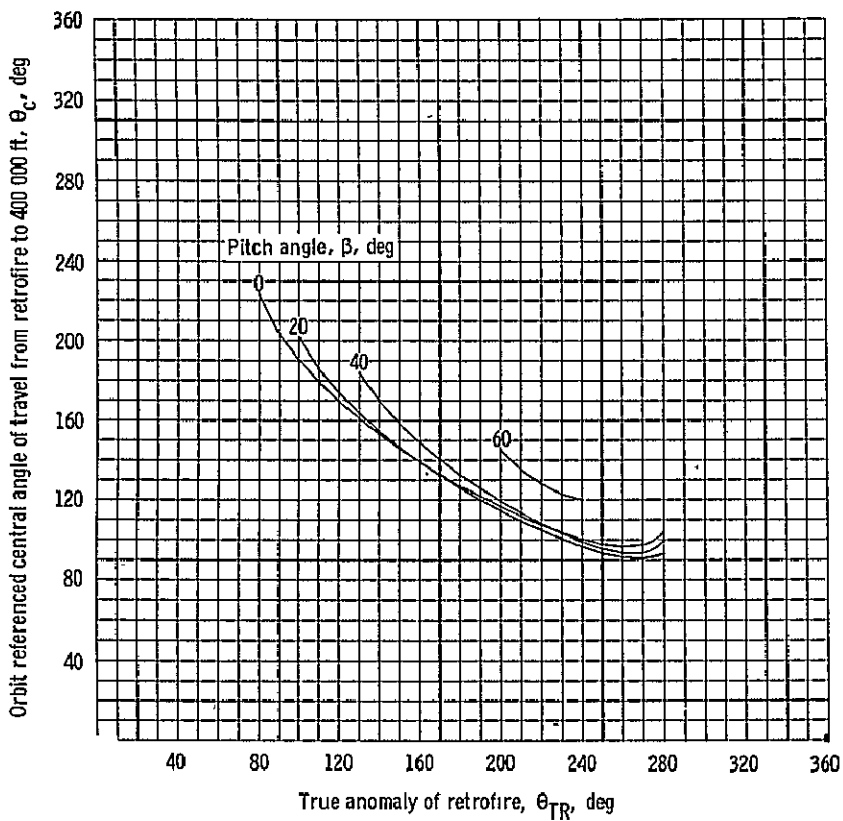
(b) Retrograde $\Delta V = 500$ fps.

Figure 32. - Continued.



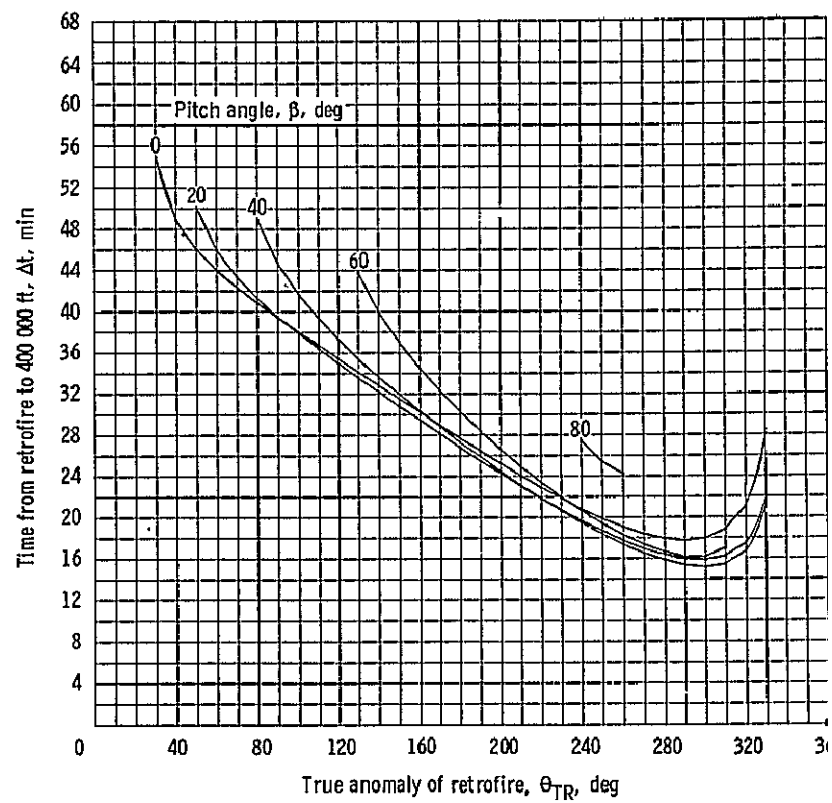
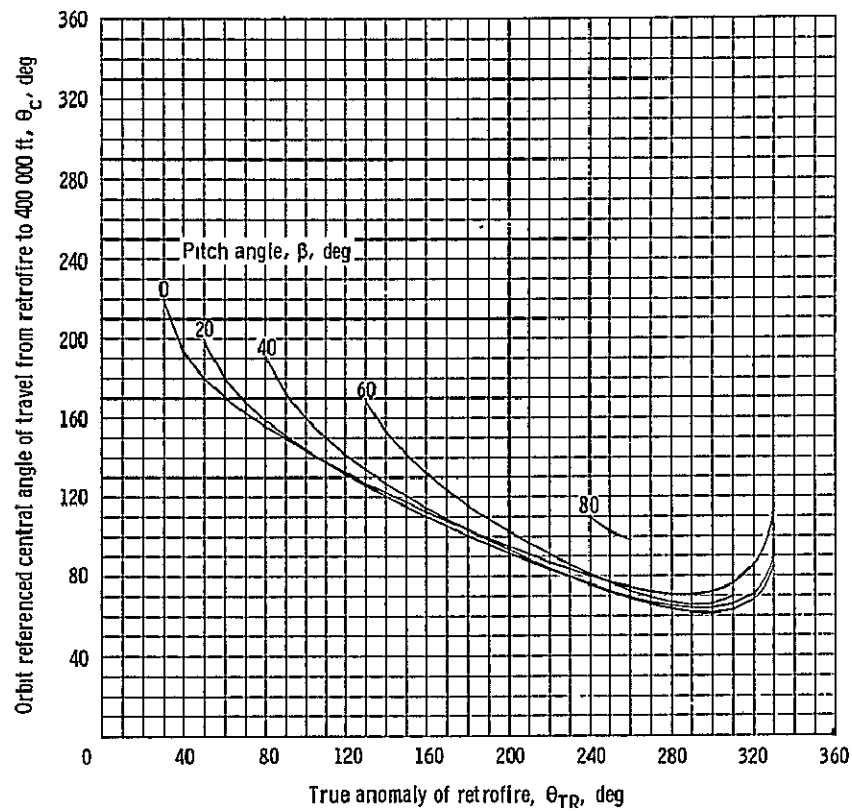
(c) Retrograde $\Delta V = 700$ fps.

Figure 32. - Concluded.



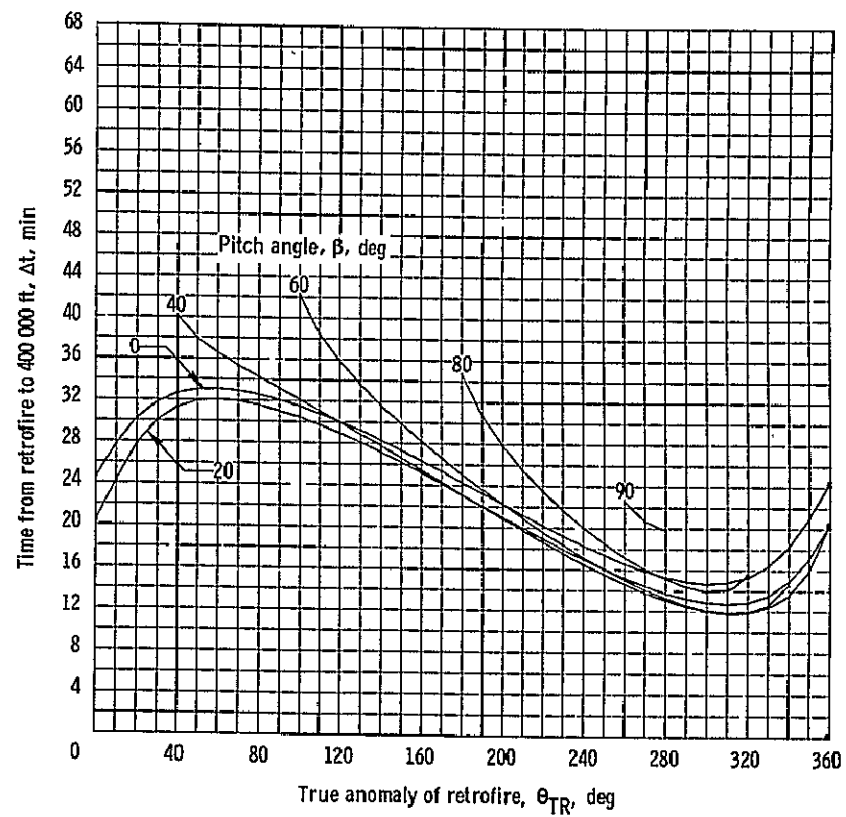
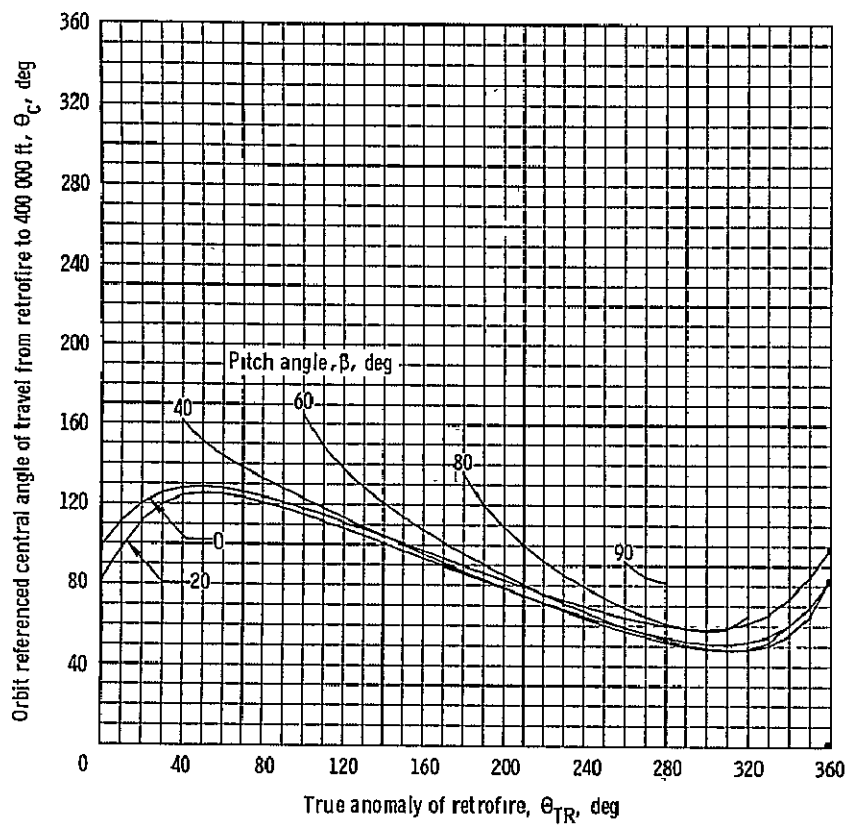
(a) Retrograde $\Delta V = 300$ fps.

Figure 33. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 400$ nautical miles and $h_p = 160$ nautical miles.



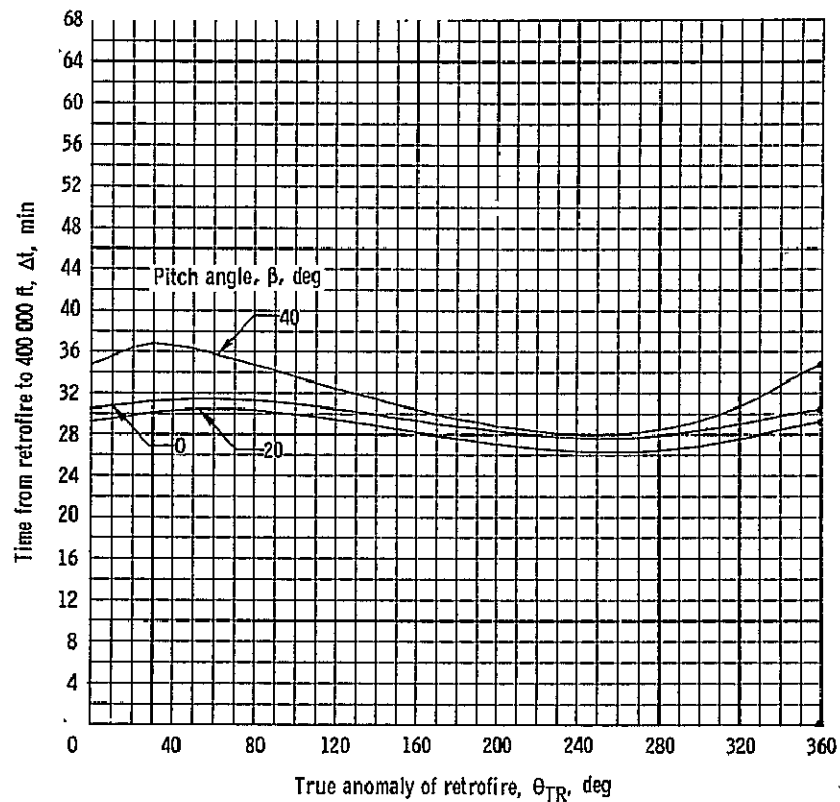
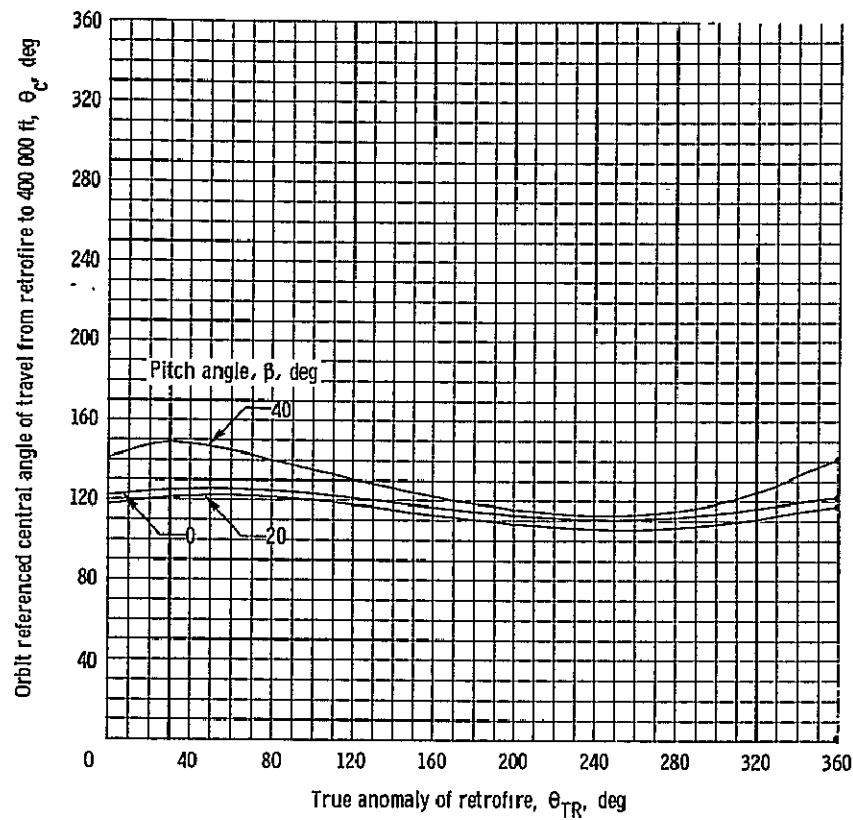
(b) Retrograde $\Delta V = 500$ fps.

Figure 33. - Continued.



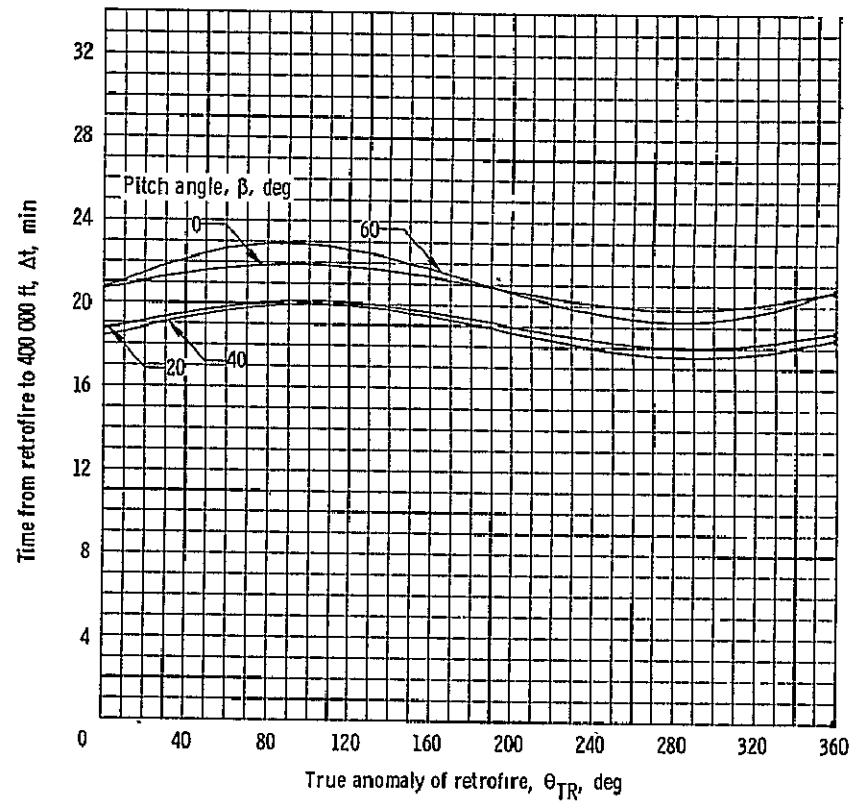
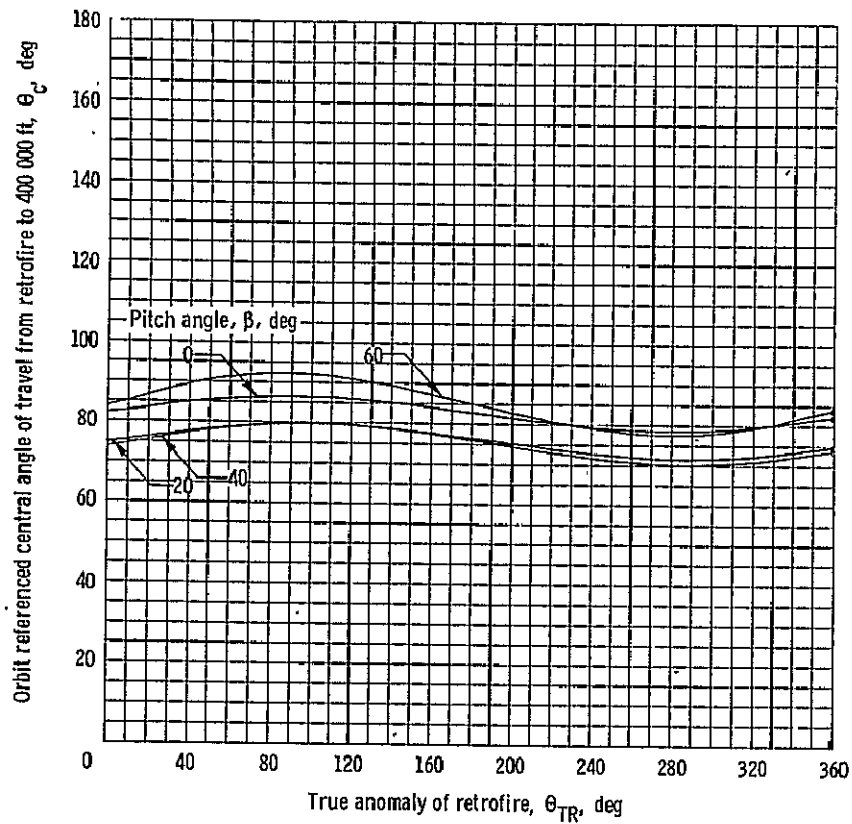
(c) Retrograde $\Delta V = 700$ fps.

Figure 33. - Concluded.



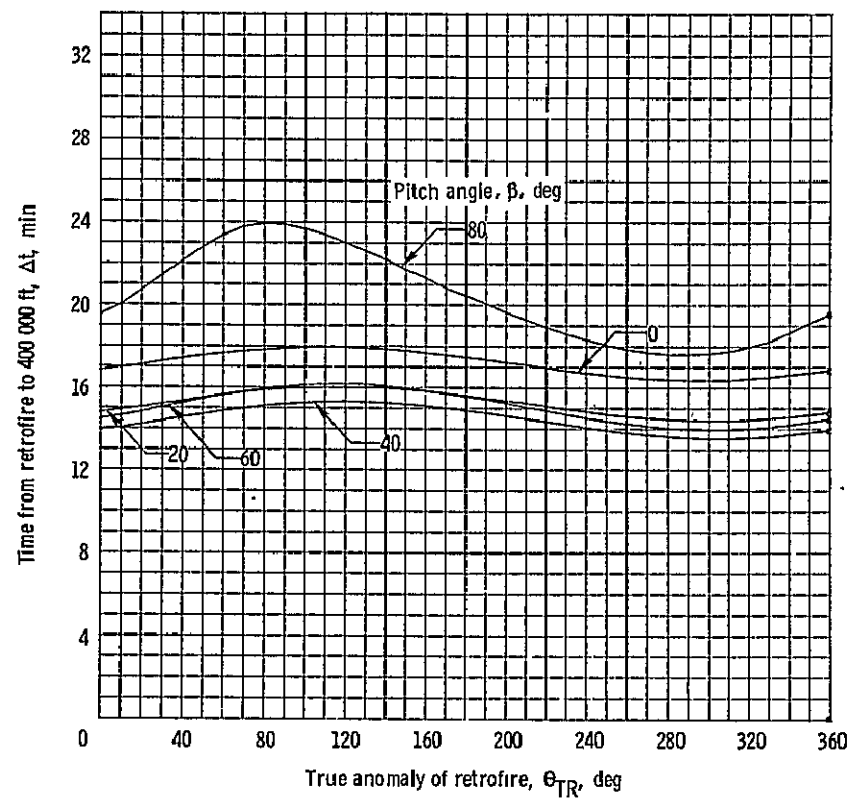
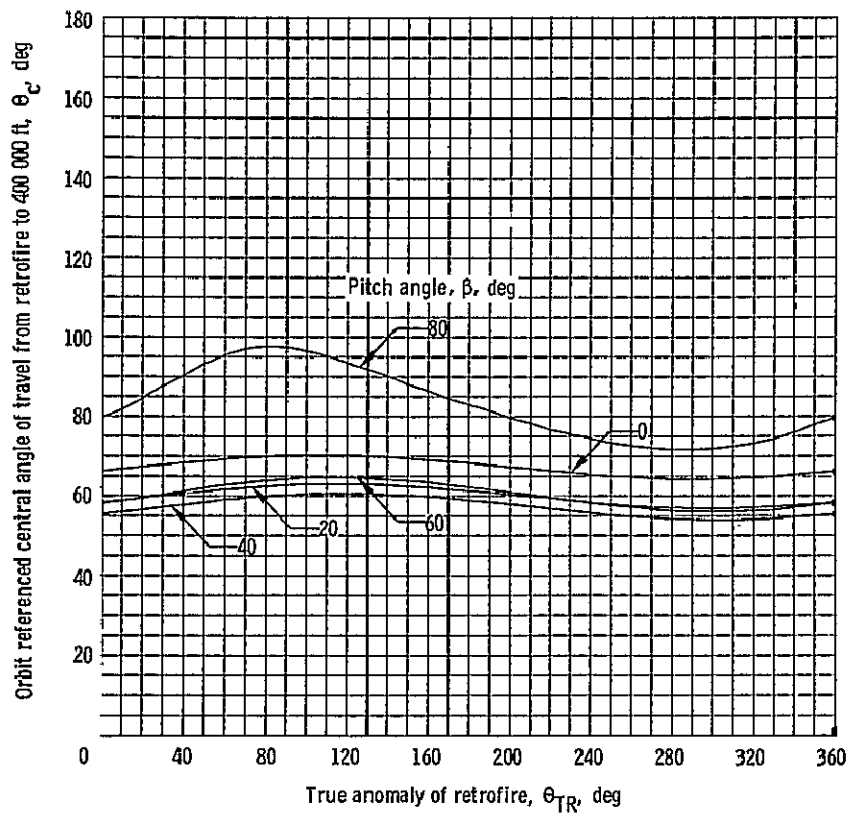
(a) Retrograde $\Delta V = 300$ fps.

Figure 34. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 200$ nautical miles and $h_p = 180$ nautical miles.



(b) Retrograde $\Delta V = 500$ fps.

Figure 34. - Continued.



(c) Retrograde $\Delta V = 700$ fps.

Figure 34. - Concluded.

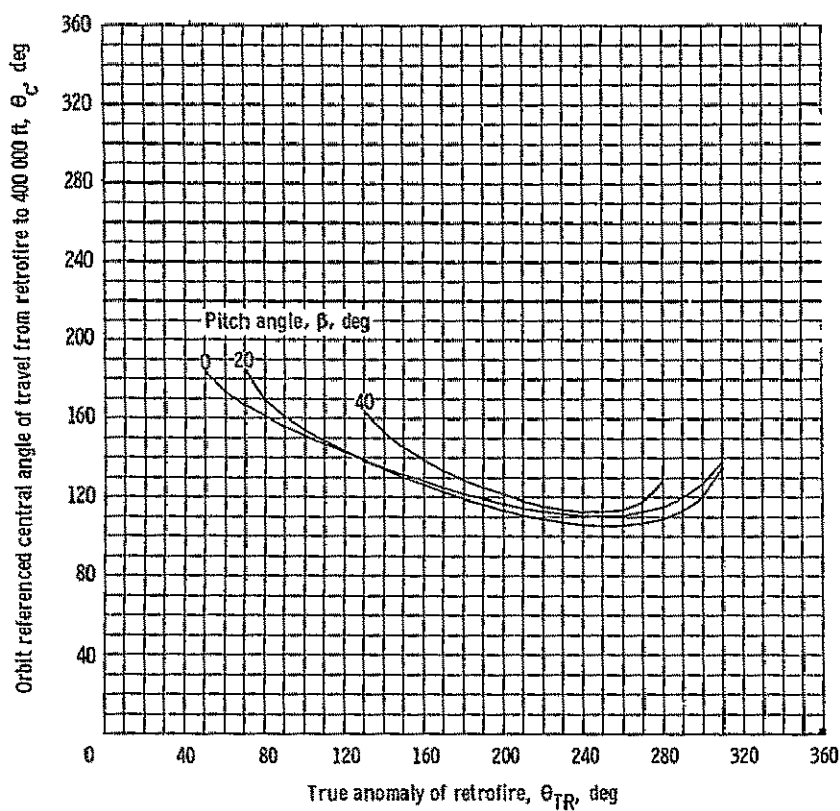
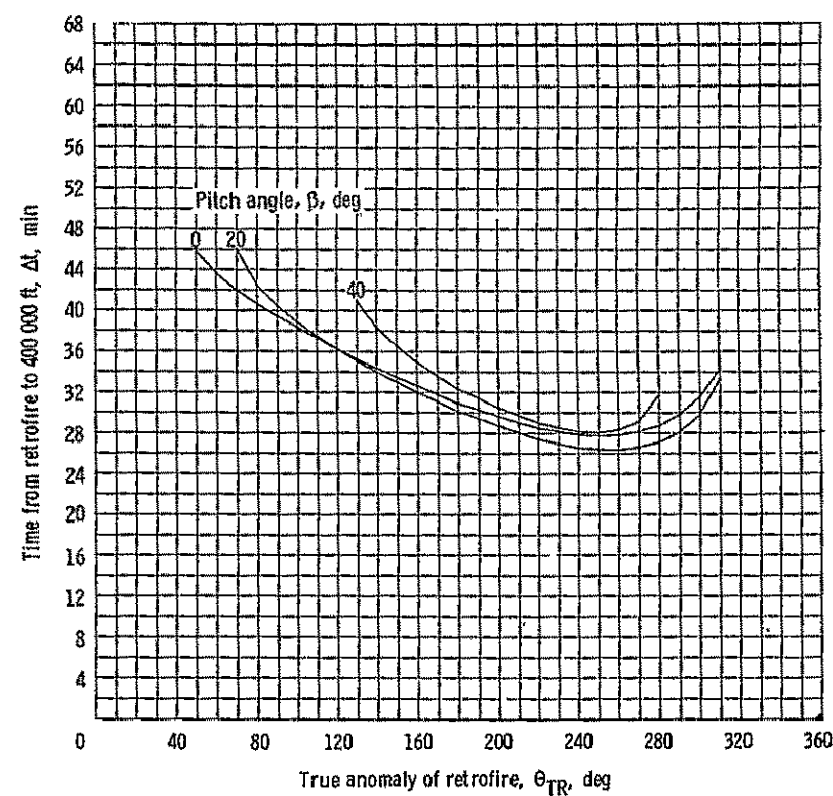
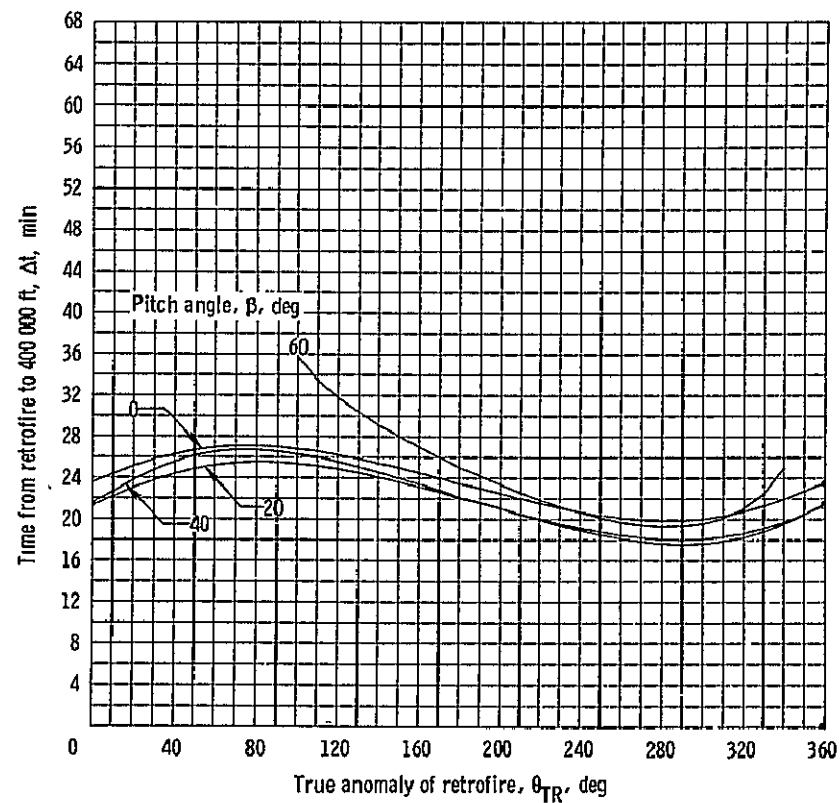
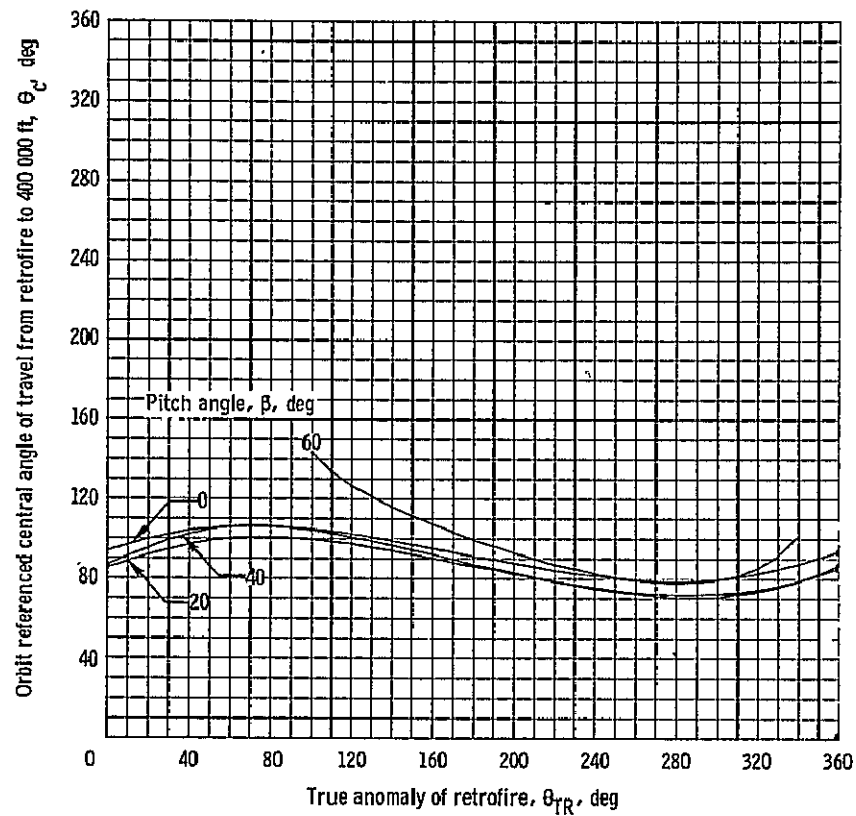
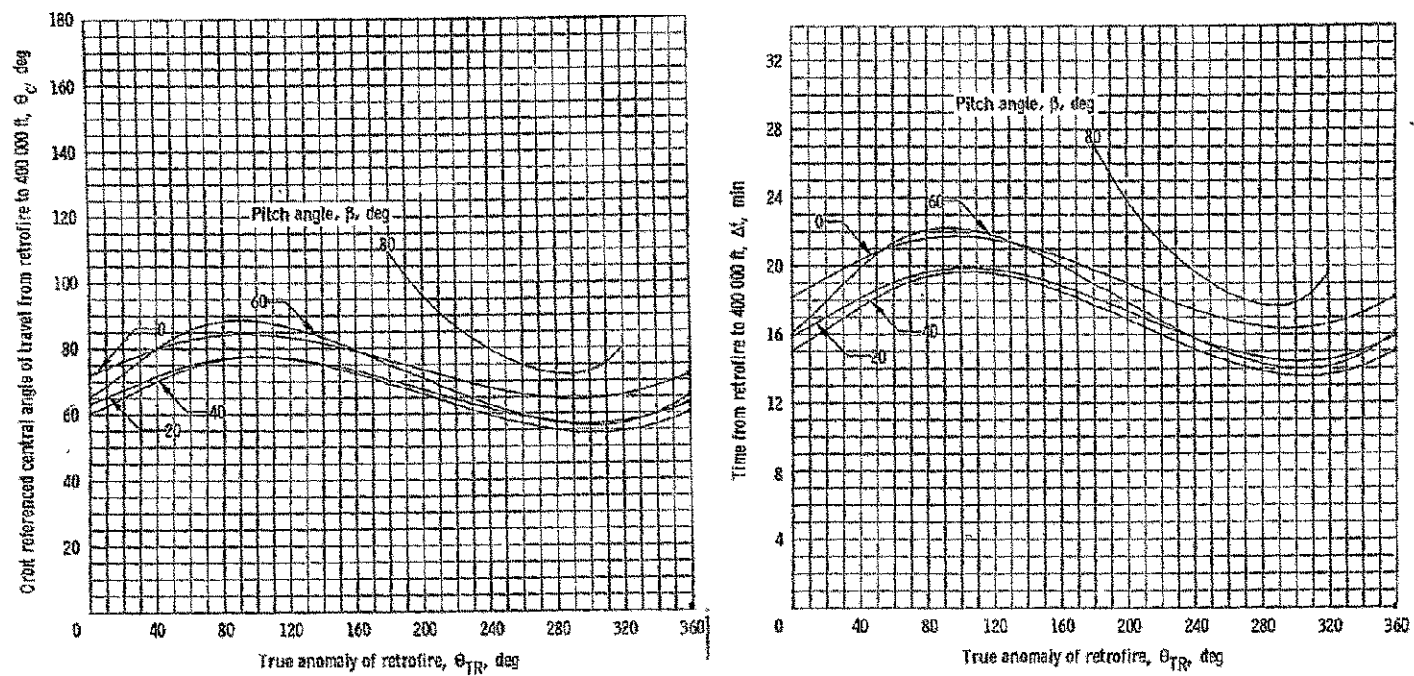
(a) Retrograde $\Delta V = 300$ fps.

Figure 35. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 250$ nautical miles and $h_p = 180$ nautical miles.



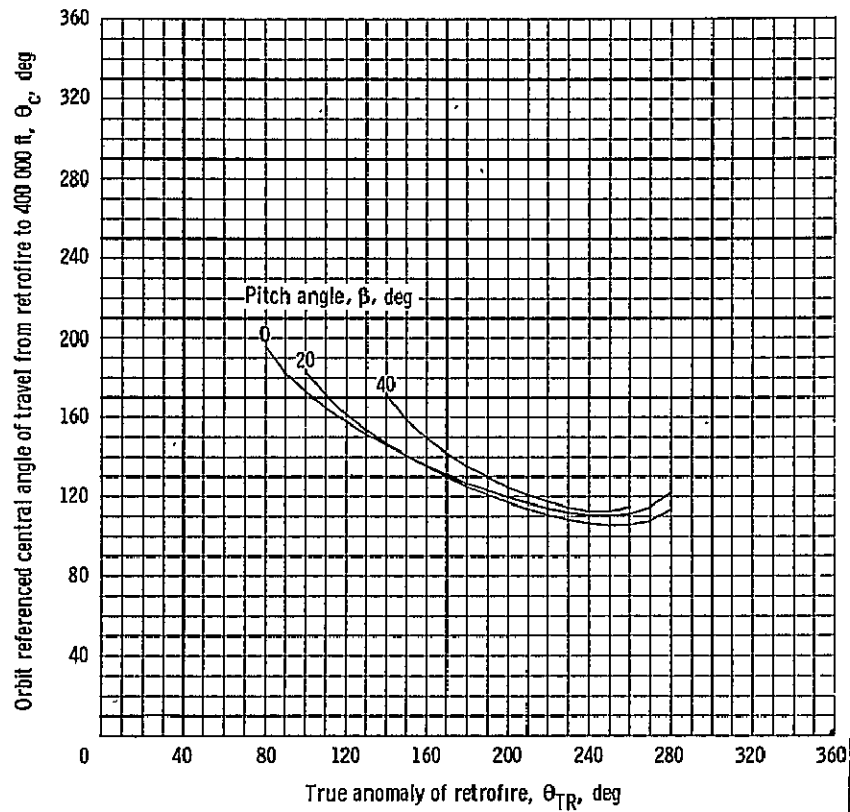
(b) Retrograde $\Delta V = 500$ fps.

Figure 35. - Continued.



(c) Retrograde $\Delta V = 700$ fps.

Figure 35. - Concluded.



(a) Retrograde $\Delta V = 300$ fps.

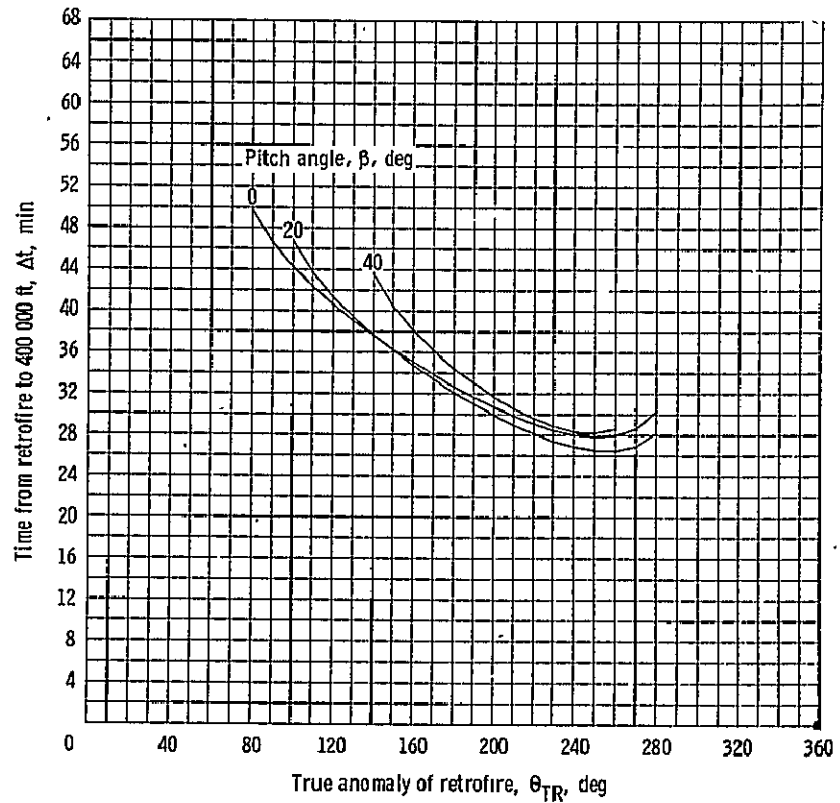
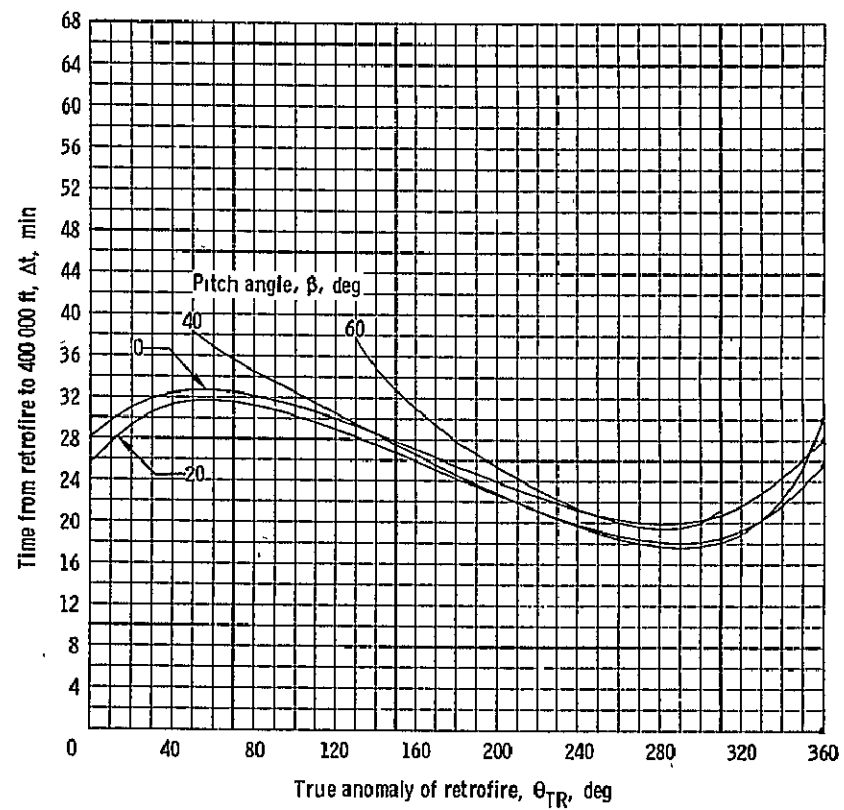
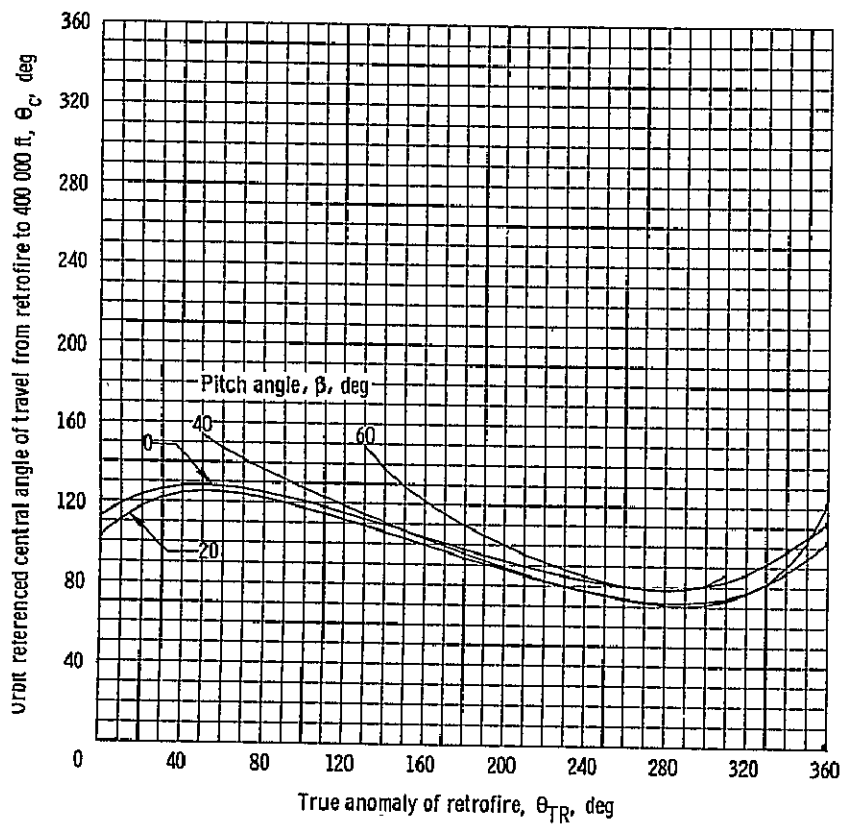
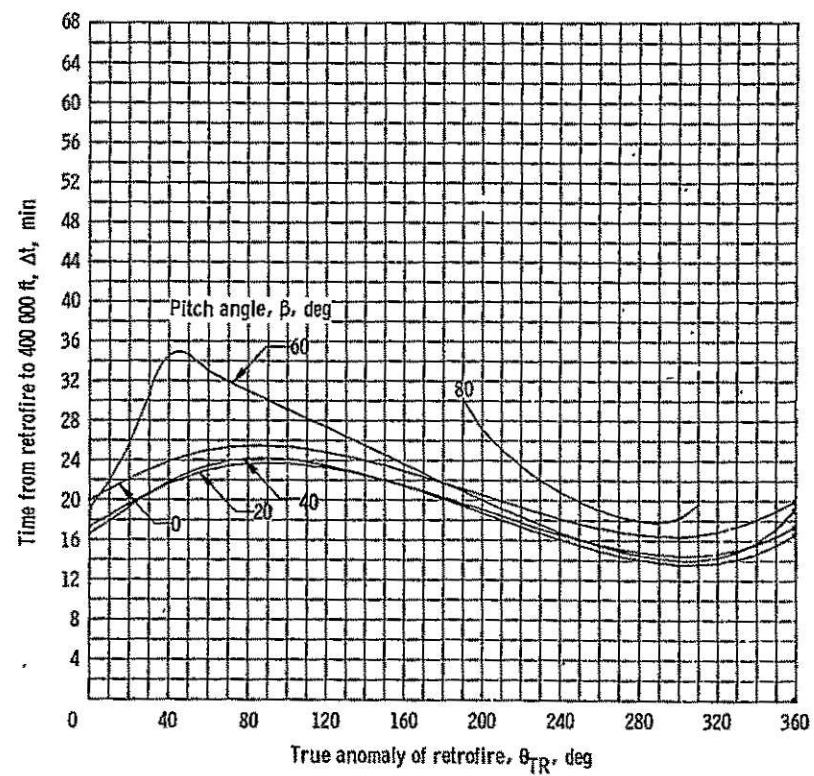
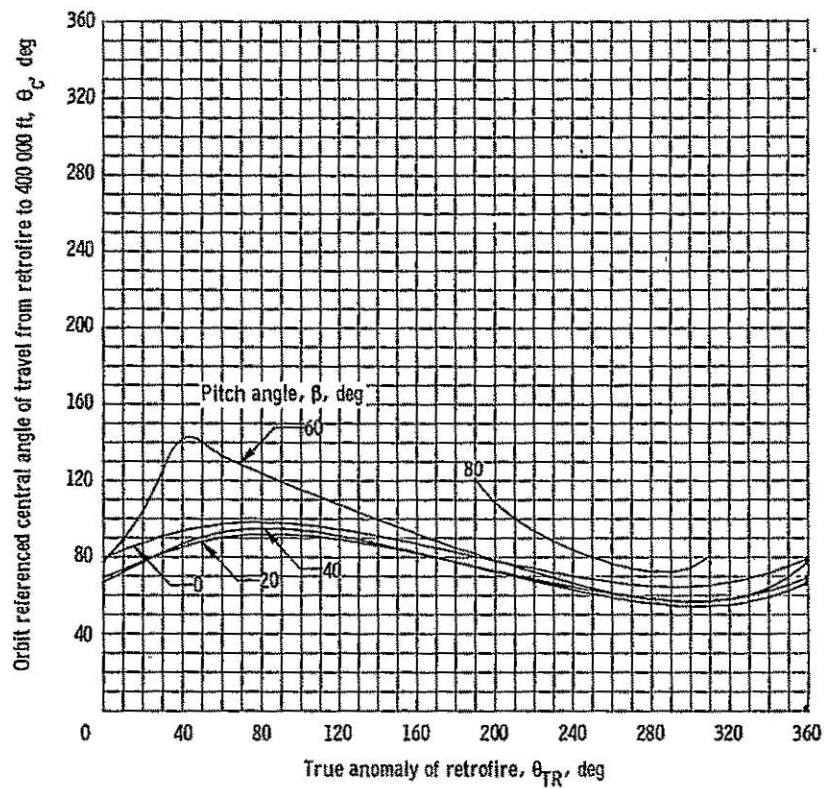


Figure 36. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 300$ nautical miles and $h_p = 180$ nautical miles.



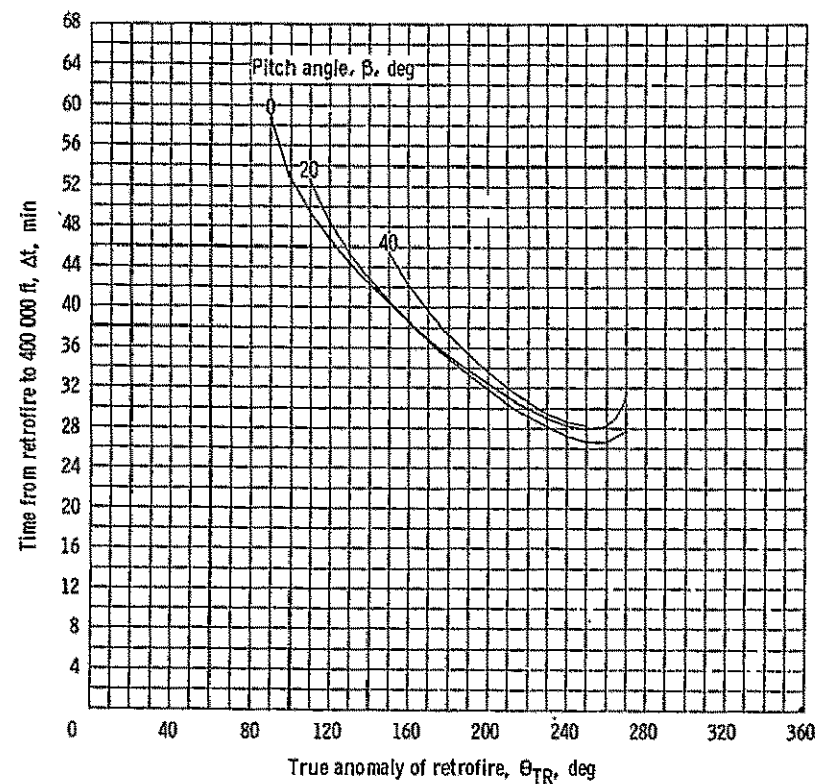
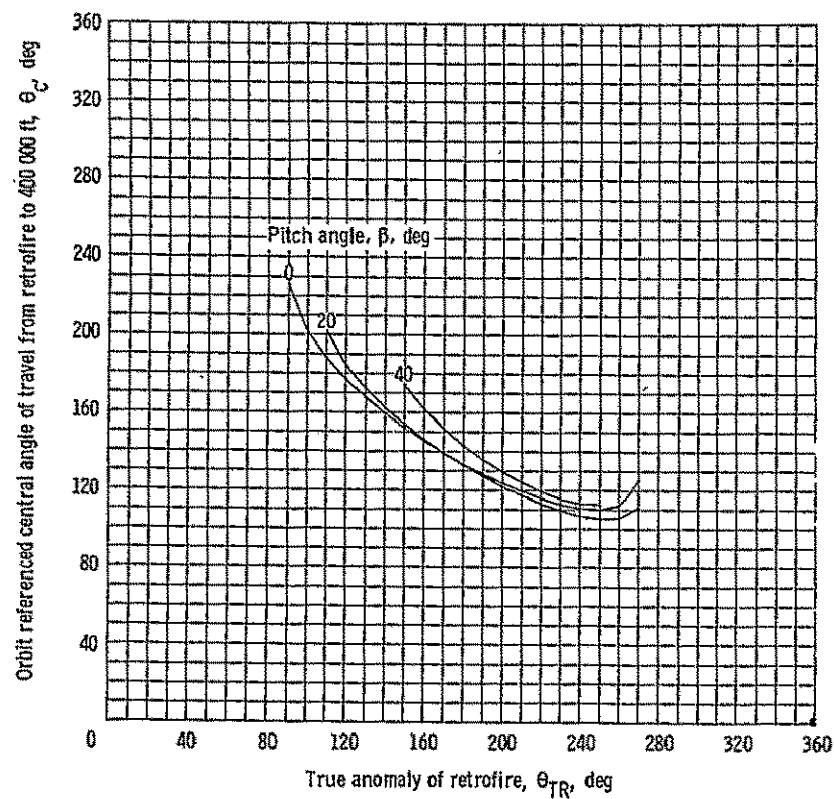
(b) Retrograde $\Delta V = 500$ fps.

Figure 36. - Continued.



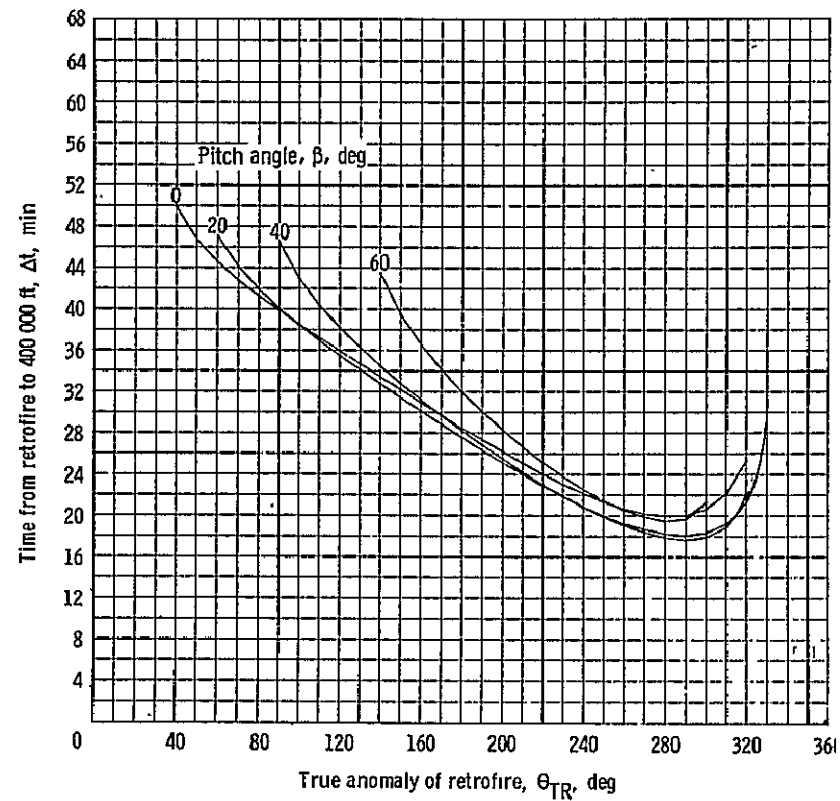
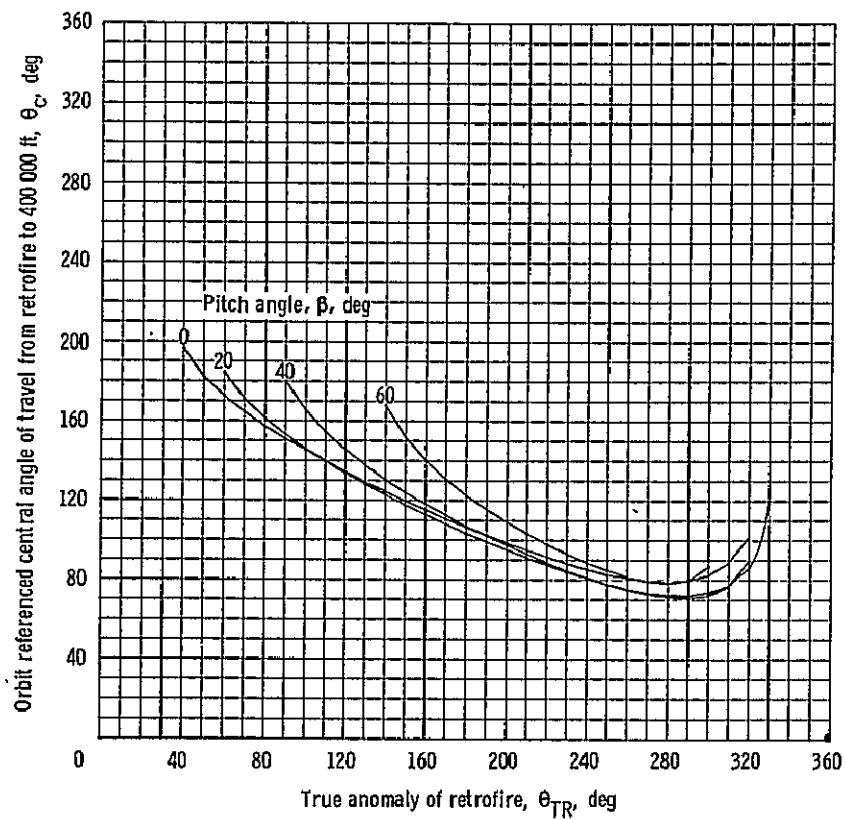
(c) Retrograde $\Delta V = 700$ fps.

Figure 36. - Concluded.



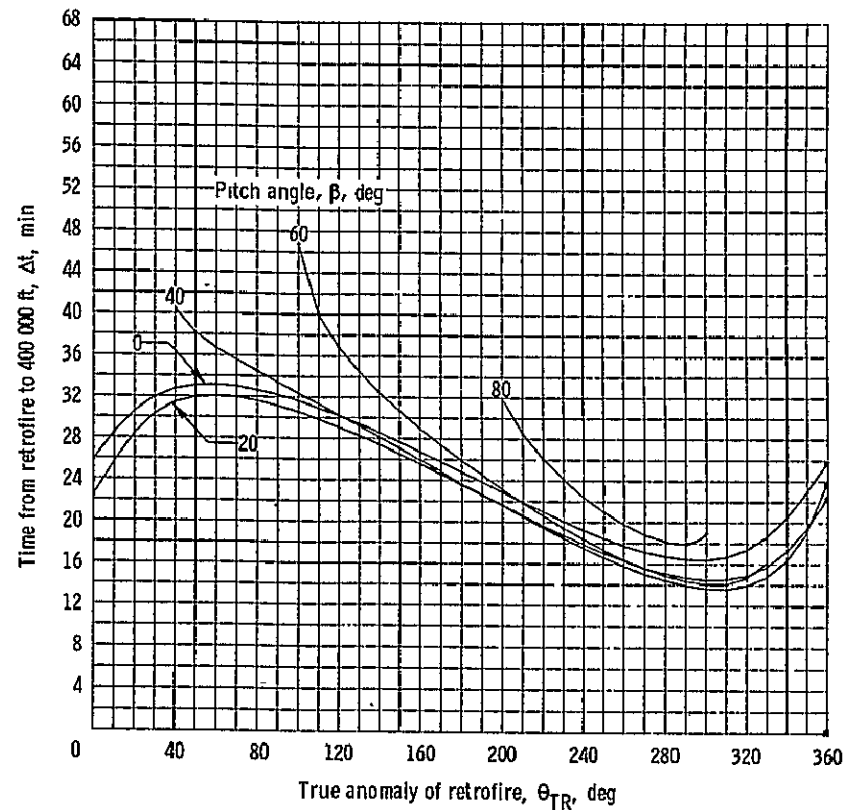
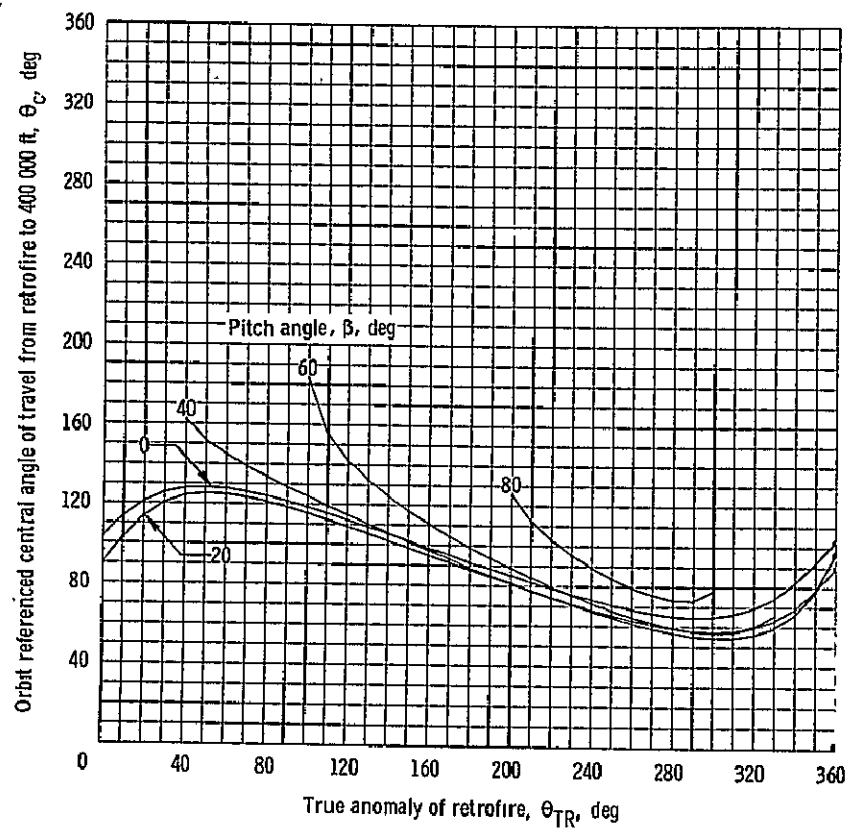
(a) Retrograde $\Delta V = 300$ fps.

Figure 37. - Orbit referenced central angle of travel and time from retrofire to 400 000 feet versus true anomaly of retrofire as functions of various pitch angles for a constant retrograde ΔV ; $h_a = 400$ nautical miles and $h_p = 180$ nautical miles.



(b) Retrograde $\Delta V = 500$ fps.

Figure 37. - Continued.



(c) Retrograde $\Delta V = 700$ fps.

Figure 37. - Concluded.

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